Estimates of Fish-, Spill-, and Sluiceway-Passage Efficiencies of Radio-Tagged Juvenile Steelhead and Yearling Chinook Salmon at The Dalles Dam, 2000

Final Report of Research during 2000

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Summary

In 2000, the U.S. Army Corps of Engineers (COE) contracted with the U.S. Geological Survey to determine spill and fish passage efficiencies at The Dalles Dam (TDA) during a 40% continuous spill condition. Our specific objectives were to: 1) determine the proportion of radio-tagged juvenile steelhead (*Oncorhynchus mykiss*) and yearling Chinook salmon (*O. tshawytscha*) that passed through the spillway and powerhouse (via turbines or sluiceway) at TDA and 2) obtain information on the behavior of radio-tagged fish in the near-dam area prior to passage.

Dam Operations: The test condition was similar to that proposed. Mean hourly percent spill ranged from 38.5 to 40.5% during the study, with an average of 39.6% during the day and 39.4% at night. Mean hourly total discharge ranged from 217.0 thousand cubic feet per second (KCFS) to 305.5 KCFS during the study period.

Number of Fish Released and Detected: From 28 April through 26 May, we radio-tagged and released 911 juvenile steelhead and 912 yearling Chinook salmon. Release sites included 1) Rock Creek, 23 km upstream from John Day Dam (JDA), 2) the JDA spillway, 3) the JDA juvenile bypass system outfall, and 4) the JDA tailrace; these fish were also used in a variety of studies at JDA. The telemetry systems at TDA detected 87% of the juvenile steelhead released and 89% of the yearling Chinook salmon released.

Travel Time, Arrival Time, and Approach Pattern: Median travel times of juvenile steelhead and yearling Chinook salmon from the Rock Creek release site to the TDA near-dam forebay

were 43.2 and 36.7 h, respectively. Median travel times of juvenile steelhead and yearling Chinook salmon released in the John Day Dam (JDA) tailrace to TDA were 12.6 h and 15.0 h, respectively. Those released as part of the JDA egress study (through the JDA spillway and juvenile bypass outfall combined) were 14.5 h and 15.9 h. Due to the release times and the variable length of time it took individual fish to reach the dam, the hour of arrival at TDA of both species was widely dispersed throughout the diel period. However, the peak arrival of both species occurred between approximately 0600 and 1400 h.

Most fish of both species were first detected (i.e., approached the dam) at the powerhouse. Ninety-four percent of the juvenile steelhead arriving during the day (0700 to 1859 h) were first detected at the powerhouse and 69% of those arriving at night (1900 to 0659 h) were first detected in this area. An average of 75% of yearling Chinook salmon arriving during the day and 68% of those arriving at night were first detected at the powerhouse.

Behavior in the Near-Dam Forebay: The median residence times in the near-dam forebay of fish arriving during the day were significantly longer than those of fish arriving at night. Median forebay residence times of juvenile steelhead in each time period ranged from 0.8 to 4.8 h if arriving during the day and from 0.2 to 0.9 h when arriving at night. Median residence times of yearling Chinook salmon arriving during the day in each time period ranged from 0.4 to 0.8 h and those arriving at night ranged from 0.3 to 0.6 h. As in 1999, median residence times of juvenile steelhead were longer than those of yearling Chinook salmon during the day, but not at night.

Fish-, Spill-, and Sluiceway-Passage Efficiencies: Most fish of each species passed the dam via the spillway, with the powerhouse (turbine) passage the second most prevalent and the sluiceway the least prevalent. Fish passage efficiencies of both species were greater during the day than at night. Juvenile steelhead fish passage efficiency (FPE) estimates were 94% during the day and 86% at night, spillway passage efficiencies (SPE) were 88% during the day and 82% at night, and sluiceway passage efficiencies (SLPE) during the day and night were 7 and 5%, respectively. The FPE of yearling Chinook salmon was 90% in the day and 80% at night, the SPE was 86% in the day and 71% at night, and the SLPE in the day and night were 4 and 8%, respectively. These results are more similar to the 64% spill treatment used in 1999 than the 30% spill treatment used in 1999. The reduction in the percent passing via the sluiceway is perhaps the most notable difference between years (1999 overall estimates: steelhead 25% during 30% spill, 9% during 64% spill; Chinook salmon 22% during 30% spill, 12% during 64% spill). However, differences in spill patterns, the number of turbines operated, and percent of water spilled between years may all have contributed to the lower sluiceway passage in 2000.

High spill effectiveness of the spill condition used in 2000 may account for the high SPE and low SLPE relative to other years. Daytime spill effectiveness estimates were 2.2:1 for juvenile steelhead and yearling Chinook salmon. Nighttime spill effectiveness estimates were 2.1:1 for juvenile steelhead and 1.8:1 for yearling Chinook salmon.

Introduction

A Supplemental Biological Opinion issued by the National Marine Fisheries Service (NMFS) recommended that spill volumes at dams on the Columbia and Snake rivers be maximized to increase juvenile salmonid (*Oncorhynchus* spp.) survival without exceeding the current total dissolved gas cap levels or other project-specific limitations (NMFS 1998). At The Dalles Dam (TDA), where it is believed that the spillway may not be a benign passage route during some spill conditions, the NMFS requested that spill volumes be limited to 64% of the total discharge pending the completion of ongoing studies of passage survival and spill efficiency and effectiveness.

Generally, a 1:1 relationship is assumed between the percent of total fish that pass through the spillway and the percentage of total river flow passing through the spillway (Whitney et al. 1997). However, it is estimated that spill effectiveness is greater than the 1:1 ratio at TDA and that a spill volume of only 31% of total river flow is needed to achieve 80% fish passage efficiency (FPE) for spring and summer migrants (Whitney et al. 1997). Other studies at TDA have indicated that 30% spill may be just as effective at passing juvenile salmonids as spill levels near 60% of the total discharge (NMFS 1998). The spillway and the ice-trash sluiceway are currently the only non-turbine routes of fish passage at TDA.

In 2000, the U.S. Army Corps of Engineers (COE) contracted with the U.S. Geological Survey to determine spill and fish passage efficiencies at TDA during a condition of continuous 40%-spill passed via the juvenile spill pattern. Our specific objectives were to: 1) determine the proportion of radio-tagged juvenile steelhead (*O. mykiss*) and yearling Chinook salmon (*O. tshawytscha*) that passed through the spillway and powerhouse (both turbines and sluiceway) at TDA and 2) obtain information about the behavior of radio-tagged fish in the near-dam area prior to passage.

Methods

Study Site

The Dalles Dam is located on the Columbia River at river km 307 (Figure 1). The dam consists of a single powerhouse of 22 turbine units and a single spillway of 23 tainter gates. The powerhouse is oriented parallel to river flow, but the spillway is perpendicular to river flow. A non-overflow wall oriented parallel to river flow connects the powerhouse and spillway. A navigation lock is located at the northwest end of the dam.

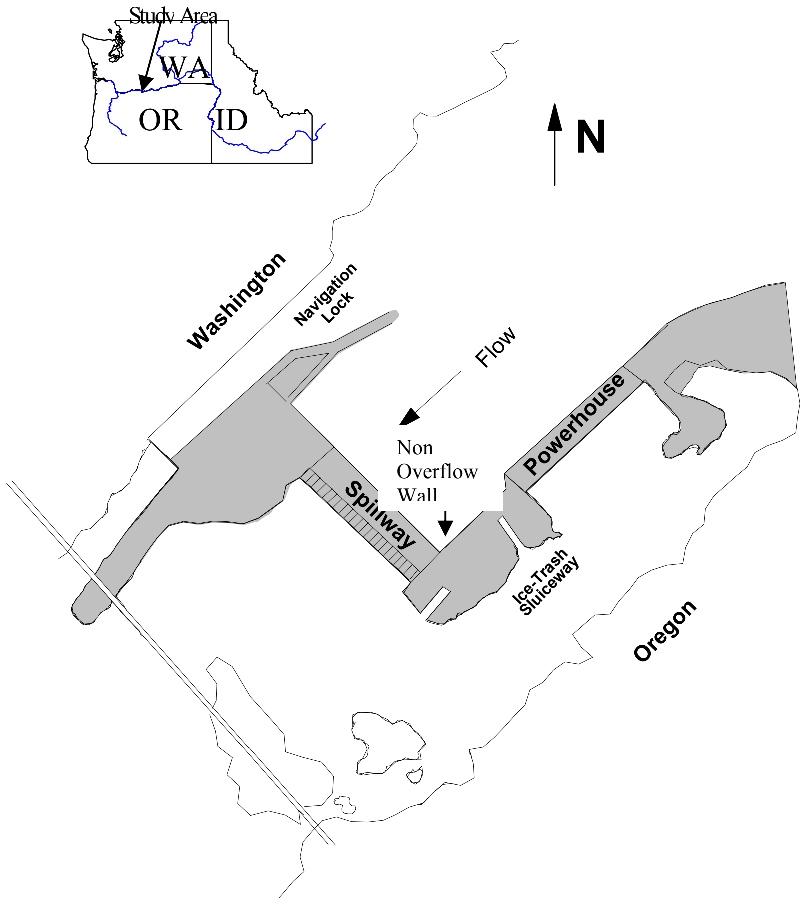

Figure 1. The Dalles Dam (river km 307) study site on the Columbia River and map indicating study site relative to the States of Washington (WA), Oregon (OR) and Idaho (ID).

Dam Operations

The spill level used in 2000 consisted of 40% continuous spill with a juvenile spill pattern. The juvenile spill pattern emphasizes spill through the northern spill bays to avoid directing fish to the shallow areas, rocks and islands on the south side of the tailrace. Juvenile salmonids in this area have prolonged tailrace residence times in an area known to harbor predators, such as the northern pikeminnow (*Ptychocheilus oregonensis*; Shively et al. 1996, Martinelli et al. 1997, Allen et al 2001). The number of spill bays in use during this pattern depends on the total discharge. Spill bays are used as needed beginning with the north bays and proceeding south until the desired spill volume is achieved; the amount of spill per bay is higher in north than in south bays. Hourly powerhouse and spillway discharge data were obtained from the COE (COE 2000).

Telemetry Receiving Equipment

Four-element Yagi (aerial) antennas were positioned along the forebay sides of the powerhouse and spillway to detect fish within about 100 m of the dam face, hereafter referred to as the near-dam area. Each antenna monitored an area in front of a pair of turbine units or spill bays. Eight 4-element Yagi antennas were also placed evenly along the forebay side of the non-overflow wall. The Yagi antennas were connected to SRX-400 receivers (Lotek Wireless, Newmarket, Ontario, Canada[1]), which recorded the telemetry data, following the methods of Hensleigh et al. (1999). Additional aerial antennas were used to monitor the tailrace and area near the upstream boundary of the forebay boat-restricted zone. The SRX-400 was configured to scan all antennas combined (the master antenna), until it received a signal and then cycle through individual aerial antennas (auxiliary antennas) to determine a more precise location of the transmitter.

Underwater antennas were used to monitor radio-tagged juvenile salmonids within about 10 m of each turbine unit or spillway tainter gate. Underwater dipole antennas were mounted at several elevations to the main pier noses between all main units, main unit 1 and fish unit 1, and the pier nose to the west (downstream) of Fish unit 2. The antennas between the western (downstream) end of the powerhouse to the pier nose between main units 4 and 5 were mounted at elevations 140, 120, 100 and 80 ft above mean sea level (msl), which correspond to water depths of 20, 40, 60 and 80 ft below the normal operating pool elevation of 160 ft above msl. Underwater antennas from the pier nose between main units 5 and 6 to the pier nose east (upstream) of main unit 22 were mounted at the upper three depths previously described. The inputs from all underwater antennas, and four aerial antennas in the sluiceway area, were monitored using a Multiprotocol Integrated Telemetry Acquisition System (MITAS), which is a PC-based telemetry data collection system (Grant Systems Engineering, Collingwood, Ontario, Canada).

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11 Reference to trade names does not imply endorsement by the U. S. Government.

Fish Tagging, Handling, and Release

This study was based on radio-tagged fish from several concurrent studies at John Day Dam (JDA). The studies at JDA were designed to determine FPE, tailrace egress times, and project survival. Tagged fish for those studies were released 1) at Rock Creek (23 km upstream of JDA), 2) through flexible hoses near the ogee crest of several spill bays, 3) through the juvenile-bypass system, and 4) in the JDA tailrace approximately 1 km below the dam. Releases at Rock Creek and the JDA tailrace occurred at 0800 and 2000 h and those through the spillway and JBS occurred at 1000 and 2200 h in each location. See Duran et al. (2001) and Beeman et al. (2003) for further details of the fish releases at JDA.

Juvenile steelhead and yearling Chinook salmon to be implanted with radio transmitters were obtained from the juvenile collection and bypass facility at JDA. Fish to be implanted were typically held at the collection facility for 12 to 24-h prior to tagging. Fish were considered suitable for tagging if they were free of injuries, severe descaling, external signs of gas bubble trauma, or other abnormalities.

Pulse-coded transmitters operating at frequencies between 150.320 and 150.800 mHz were used to allow each individual fish to be recognized. Two sizes of these transmitters were used to accommodate the different sizes of the two species. Transmitters implanted in steelhead were 8.2 mm (diameter) x 18.9 mm and weighed 1.8 g in air (Lotek Wireless model 3GM), while the transmitters implanted in the yearling Chinook salmon were 7.3 mm x 18.0 mm and weighed 1.4 g in air (Lotek Wireless model 3KM). Transmitters were gastrically implanted in both species using the methods of Martinelli et al. (1998).

Following tagging, fish were held in tanks at the juvenile bypass collection facility for 20 to 28 h. After the holding period, the tanks were checked for mortalities and fish were transported either to Rock Creek and released into the north river channel or were released in the tailrace of JDA. Tailrace releases were made about 300 m downstream of the tailrace boat restricted zone below the north spill bays, through tubes into spill bays 2, 10, and 18, and through the juvenile bypass system outfall.

Data Management and Analysis

Data from radio-telemetry receivers and the MITAS system were typically downloaded every other day and imported into SAS (SAS Institute Inc., Cary, NC, USA) for subsequent proofing and analyses. The data were proofed to eliminate non-valid records including background noise, single records of a particular channel and code, records that were collected prior to the known release date and time, and records known to be fish eaten by avian predators. Generally, the minimum amount of data required to validate the presence of a radio-tagged fish was a combination of two master antenna and one auxiliary antenna detections or three master antenna detections within 1 to 2 min of each other.

The location and time an individual fish was first detected by telemetry receivers on the dam face was considered the route and time of entrance into the near-dam area. Similarly, the last detection of an individual fish on the receivers on the dam face was considered the route and time of passage through the dam. However, radio-tagged fish were often detected on multiple auxiliary antennas where zones of coverage overlapped, making data reduction necessary. Fish detected on more than one auxiliary antenna within a two-minute period at the time of passage were assigned to a single passage location corresponding to the antenna where the highest strength signal was recorded, and all other records were excluded. A two-minute interval was chosen because it approximately coincided with the upper boundary of time needed to complete a scan cycle if several fish were present at any given time. Manual tracking on the dams has verified that the last detection by telemetry receiving stations is typically a good estimate of the passage route (Sheer et al. 1997; Holmberg et al. 1998; Hensleigh et al. 1999).

Fish passage efficiency (FPE) was determined as the proportion of the total number of radio-tagged juvenile steelhead or yearling Chinook salmon exiting the near-dam TDA forebay that passed via non-turbine routes (i.e., through the spillway or the ice-trash sluiceway) multiplied by 100%.

$$\text{FPE} = \frac{\text{fish last detected at spillway} + \text{fish last detected at sluiceway}}{\text{fish last detected at spillway} + \text{fish last detected at sluiceway} + \text{fish last detected at turbines}} \qquad \text{Equation 1}$$

Similarly, spill passage efficiency (SPE) and sluiceway passage efficiency (SLPE) were calculated as the proportion of the total number of radio-tagged juvenile steelhead or yearling Chinook salmon that passed through the spillway or sluiceway, respectively, multiplied by 100%.

$$\text{SPE} = \frac{\text{fish last detected at spillway}}{\text{fish last detected at spillway} + \text{fish last detected at sluiceway} + \text{fish last detected at turbines}} \qquad \text{Equation 2}$$

$$\text{SLPE} = \frac{\text{fish last detected at sluiceway}}{\text{fish last detected at spillway + fish last detected at sluiceway + fish last detected at turbines}} \quad \text{Equation 3}$$

Spill effectiveness was calculated as SPE divided by the proportion of total dam discharge being spilled. This index was used to help identify potential relations between spill discharges, FPE or SPE estimates, and juvenile salmonid passage behavior.

Statistical analyses comparing the passage indices calculated for day and night periods were completed using logistic regression after adjusting for differences in time periods (see next paragraph for description of time periods). Logistic regression is not based on assumptions of linearity, normality, or homoscedasticity. Logistic regression estimates the probability of an event (e.g., passing via a non-turbine route) after converting the dependent variable to a logit (the natural log of the event occurring or not). An "odds ratio" is calculated from the odds of the dependent variable occurring in each of the two classes (i.e., day and night passage), and from this, the relative importance of the independent variables in terms of the effects on the dependent variable is estimated (similar to a beta weight in a least-squares regression). For example, if the hypothetical odds ratio between day and night FPE is 5, the probability of passing via a non-turbine route during the day is 5 times greater than during the night.

Diel passage data were split into nine time periods to assess seasonal variation. The number of periods used for analysis was arbitrarily determined by increasing the period sizes in 1-d increments until the number of fish detected within a day or night period was always more than 1, was generally more than 10, and the resulting estimates (i.e., FPE, SPE, or SLPE) were rarely 1 (meaning that all detected fish passed by that route). This ensured that the logistic regression would function properly (C. Pereira, personal communication). Time periods 1-8 were 3 d in duration, but period 9 was 6 d in duration to allow sufficient numbers of tagged fish to pass the dam for analysis. Overdispersion was assessed within each species by examining the models' residual deviance divided by residual degrees of freedom. Ninety-five percent profile likelihood confidence intervals were calculated for the overall odds ratio. In one case the algorithm did not converge (the juvenile steelhead day and night FPE in period 9 were both 1.0) and data from periods 8 and 9 were pooled. Single seasonal estimates of the passage indices with 95% profile likelihood confidence intervals for each diel period were calculated when there was no evidence of overdispersion or time period effects.

Residence time in the near-dam area, defined as the amount of time between the first and last detections in the forebay, was calculated for each radio-tagged fish detected in the near-dam forebay area (residence times were not calculated for fish detected only at entrance and exit stations). These residence times are minimum estimates of the actual time that radio-tagged fish spent in the near-dam area due to the chance that a fish might have been in the near-dam area for an unknown amount of time prior to their first detection and following their last detection.

Diel approach and passage patterns among time periods were compared graphically. Diel residence times within species were compared controlling for block effects using Friedman's Chi-square test. Results of this test and others throughout this report were considered statistically significant when $P \leq 0.05$.

The detection efficiencies of the telemetry arrays at the powerhouse and spillway were calculated using a "double array" system as described by Lowther and Skalski (1997). This method is based on the number of fish detected and undetected at each of two arrays to determine the detection probability of each array, and ultimately, the combination of the two arrays (Jim Lady, University of Washington, personal communication). In a double-array system, the detection probability of one array is calculated as:

$$P1 = 11/(11+01) \qquad \text{Equation 1}$$

where 11 denotes fish that were detected on both arrays and 01 denotes those not detected on the first array, but detected on the second. The detection probability of the second array is calculated as:

$$P2 = 11/(11+10) \qquad \text{Equation 2}$$

where 10 denotes those detected on the first array, but not the second. The overall detection probability of the combined arrays is calculated as:

$$P12 = 1-((1-P1)(1-P2)) \qquad \text{Equation 3.}$$

The numbers of fish detected at each array are then adjusted by dividing the numbers detected at an array by the results of Equation 3 prior to calculation of the passage indices (e.g., FPE). Thus, the adjusted FPE would be calculated as:

$$FPE_{adj} = ((sp\# / P12_{\mathrm{spillway}}) + (sl\# / P12_{\mathrm{sluiceway}}))/ ((ph\# / P12_{\mathrm{powerhouse}}) + (sp\# / P12_{\mathrm{spillway}}) + (sl\# / P12_{\mathrm{sluiceway}})) \qquad \text{Equation 4,}$$

where sp#, sl# and ph# are the numbers of fish detected passing the spillway, sluiceway and powerhouse, respectively. For the purpose of this exercise, the forebay aerial and underwater arrays at the powerhouse and spillway were each considered as a single upstream array (*P1*) for that route of passage and the aerial antennas in the tailrace of each area were considered the downstream arrays (*P2*). There was only one antenna system installed in the sluiceway (four 4-element Yagi antennas with combined inputs), so the detection efficiency associated with this route of passage could not be determined using this method.

Results

Dam Operations

The mean hourly percent spill discharges at TDA during the spring were similar to the 40% spill proposed during the design phase (Table 1; Appendix A). The mean hourly percent spill was 39.6% (range 27.7 to 47.0 %) during the day and 39.4% (range 29.3 to 46.9%) during the night. Mean hourly total discharge was 254 thousand cubic feet per second (KCFS) (range 159 to 394 KCFS) during the day and 261 KCFS (range 195 to 356 KCFS) at night.

Number of Fish Released and Detected

A total of 911 juvenile steelhead and 912 yearling Chinook salmon released by studies at JDA were used for this study (Table 2). These included fish released at Rock Creek from 01 May to 24 May, those released through the spillway and bypass outfall from 28 April to 26 May, and those released in the JDA tailrace from 02 May to 25 May. Juvenile steelhead from all releases combined had a mean fork length of 219 mm (range 103 to 290 mm) and a mean weight of 87 g (range 36 to 205 g). Yearling Chinook salmon from all releases combined had a mean fork length of 176 mm (range 125 to 225 mm) and a mean weight of 55 g (range 21 to 125 g). Detailed summaries of all releases are presented in Appendices B to G. The mean tag-weight-to-body-weight ratios of juvenile steelhead and yearling Chinook salmon were 2.1 % (range 0.9 to 5.0%) and 2.5% (range 1.1 to 6.7%). Telemetry equipment at the dam detected 87% of the juvenile steelhead released and 89% of the yearling Chinook salmon released.

Table 1. Mean hourly percentages of total discharge spilled and mean hourly total discharge (KCFS) at The Dalles Dam during nine blocks, 02 May through 01 June 2000. Day spill discharge was considered to occur from 0700 h through 1859 h and night spill discharge was from 1900 h through 0659 h. Each block was3 d, except block 9, which was 6 d. Std=standard deviation.

		Hourly total discharge					
	Spill	Day			Night		
Period	condition	Mean	Std	Range	Mean	Std	Range
		Hourly percent spill					
	Spill	Day			Night		
Period	condition	Mean	Std	Range	Mean	Std	Range
1	40	38.5	3.8	27.7-42.7	34.6	3.7	29.3-40.7
2	40	39.8	2.0	30.6-43.4	40.3	2.0	35.8-46.9
3	40	38.6	1.9	33.9-42.1	39.8	2.0	33.1-42.7
4	40	40.1	1.0	37.7-42.2	40.1	1.0	36.8-41.1
5	40	40.5	0.9	38.9-43.5	39.9	0.9	38.1-42.0
6	40	39.8	1.2	37.9-42.3	40.2	1.5	37.8-43.4
7	40	39.8	1.2	37.0-43.4	39.7	1.0	36.5-42.6
8	40	39.7	1.8	35.8-47.0	39.8	0.8	38.2-41.2
9	40	40.1	0.8	38.6-42.3	39.8	0.9	38.2-43.5
1	40	263.4	34.3	214.8-360.9	305.5	29.3	245.5-356.1
2	40	291.4	40.3	230.6-394.2	273.0	32.3	216.4-329.9
3	40	279.2	34.6	213.5-352.0	253.1	33.9	195.9-301.9
4	40	260.5	34.4	214.6-321.1	254.8	18.2	226.6-300.5
5	40	235.3	19.9	184.0-277.4	259.0	42.2	179.5-334.6
6	40	244.5	18.3	212.4-282.4	245.6	26.7	199.1-287.2
7	40	219.1	33.2	167.3-302.8	261.8	23.6	193.6-294.8
8	40	275.6	20.1	225.9-324.1	272.8	28.5	202.3-314.3
9	40	217.0	26.2	159.4-250.6	226.7	29.1	179.8-282.8

Table 2. Number of radio-tagged juvenile steelhead and yearling Chinook salmon released 23 km above the John Day Dam (JDA) at Rock Creek (RCR), in the John Day Dam tailrace (JDT), and through spill bays or the juvenile-fish-bypass system at JDA as part of the JDA egress study (JDE), and the percent of fish detected by radio-telemetry receivers at The Dalles Dam, spring 2000.

	Juvenile steelhead		Yearling Chinook		Total	
Release site	Number released	Percent detected	Number released	Percent detected	Number released	Percent detected
RCR	487	82.5	484	86.2	971	84.3
JDT	286	98.3	284	94.4	570	96.3
JDE	138	79.7	144	86.1	282	82.9
Overall	911	86.8	912	88.9	1823	87.8

Arrival Time and Approach Pattern

The hour of arrival at TDA of both species was dispersed throughout the diel period (Figure 2). However, the arrivals of juvenile steelhead peaked near late morning. Yearling Chinook salmon arrival was also higher during this time, but to a lesser degree. Juvenile steelhead and yearling Chinook salmon median travel times from the Rock Creek release site to the TDA near-dam forebay were 43.2 and 36.7 h, respectively. The median travel times of juvenile steelhead and yearling Chinook salmon released at the JDA tailrace were 12.6 h and 15.0 h, respectively. Those released as part of the JDA egress study (spillway and juvenile bypass releases combined) were 14.5 h and 15.9 h.

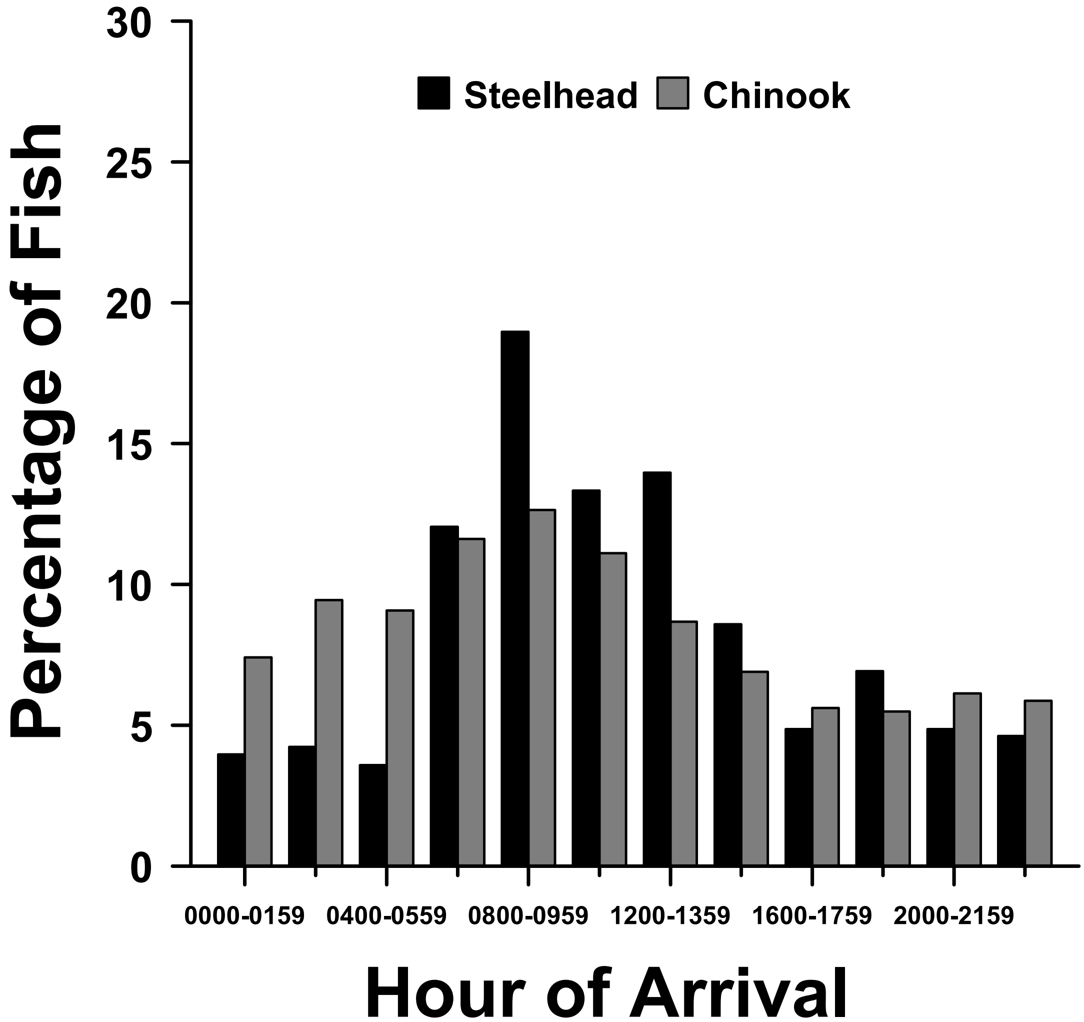

Figure 2. Diel distribution of radio-tagged juvenile steelhead and yearling Chinook salmon arrival in the near-dam forebay of The Dalles Dam among 2 h time intervals, 02 May through 01 June 2000. Sample sizes: juvenile steelhead = 742; yearling Chinook salmon = 754.

Most fish were first detected at the powerhouse, with the remainder about evenly divided between the spillway and non-overflow wall (Figure 3). A total of 93.5% of juvenile steelhead arriving during the day were first detected at the powerhouse, with 3.5% at the spillway and 3.0% at the non-overflow wall. The proportions of first detections at night were 69.4%, 16.2% and

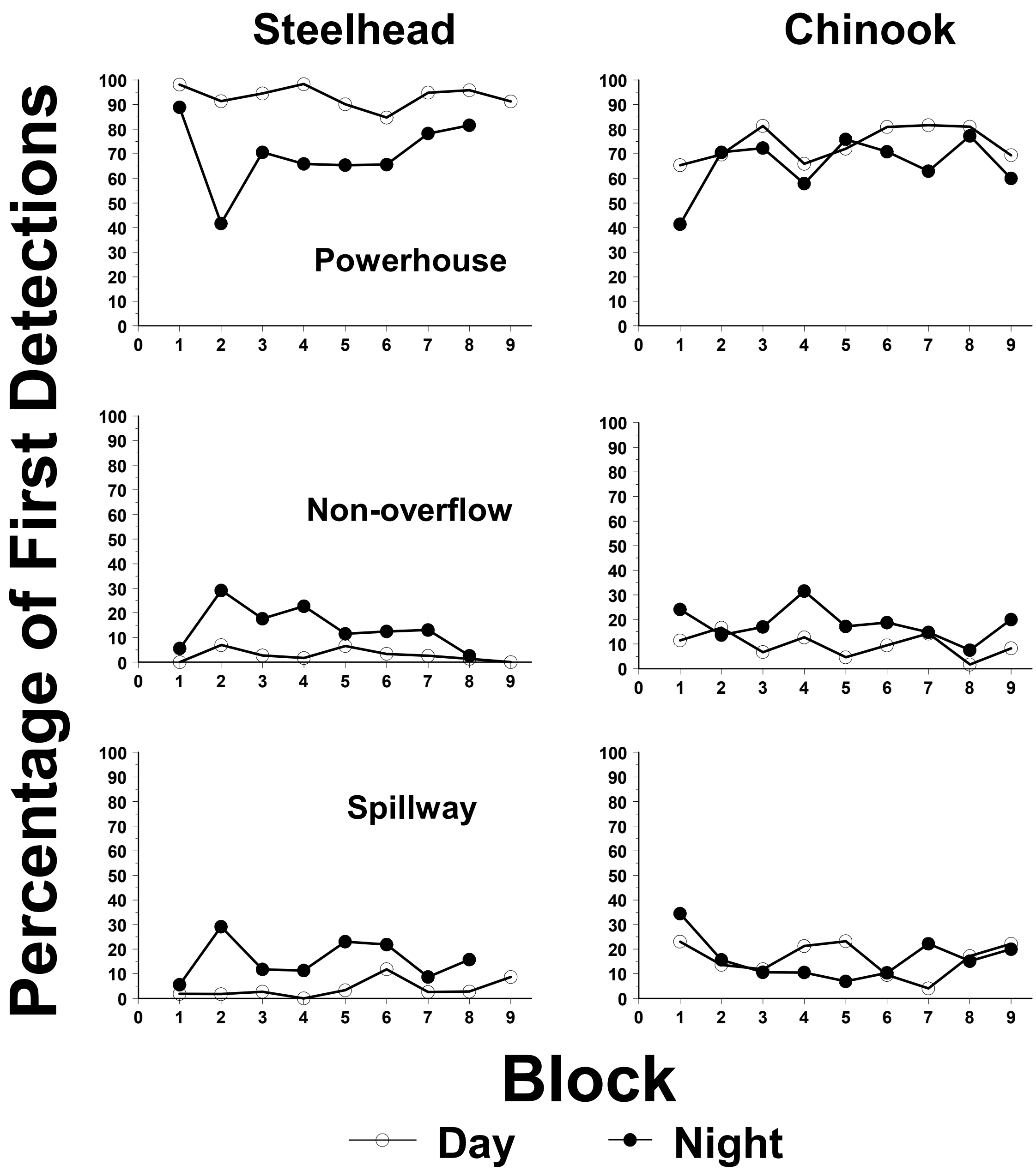

Figure 3. Distribution of juvenile steelhead and yearling Chinook salmon first detections among the powerhouse, non-overflow wall, and spillway radio-telemetry receivers in The Dalles Dam near-dam forebay during 40% spill discharge, spring 2000. Time periods represent 3 day intervals from 02 May through 01 June with the exception of period 9 which spanned 6 days. Day = 0700-1859 h, Night = 1900-0659 h. During period 9 no steelhead were first detected during the night period. Sample sizes: steelhead day = 23-78, night = 17-44; Chinook day = 26-

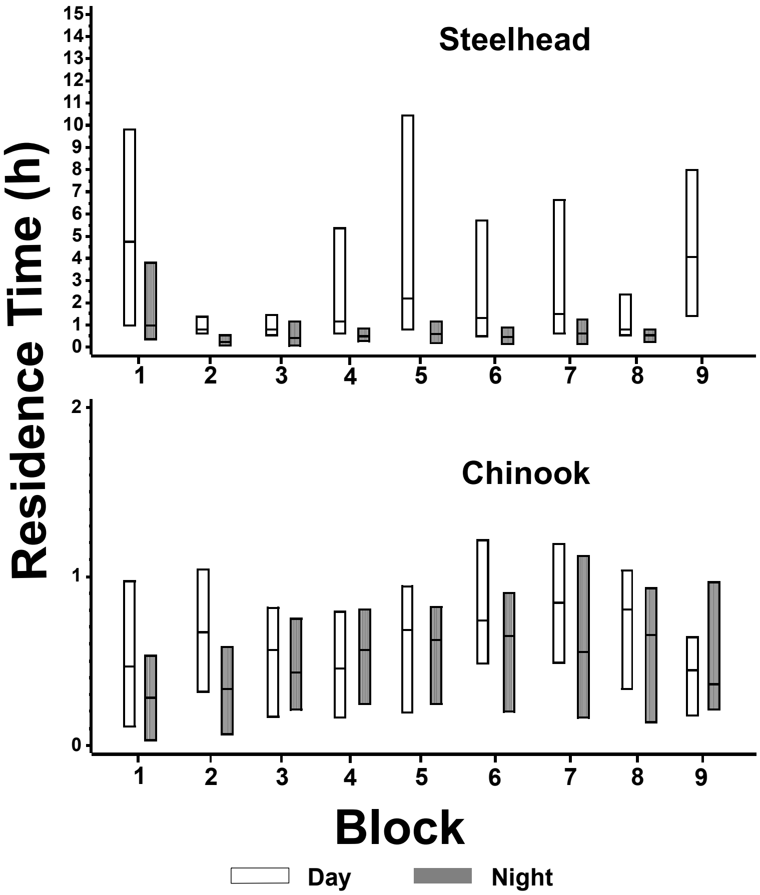

Figure 4. Twenty-fifth, 50th (median), and 75th percentiles (lower, middle, and upper horizontal lines on bars) of radio-tagged juvenile steelhead and yearling Chinook salmon forebay residence times (h) by diel time of arrival during continuous 40% spill discharge at The Dalles Dam, spring 2000. Time periods represent nine 3-day intervals from 02 May through 01 June 2000. Diel periods: day=0700-1859 h, night=1900-0659 h. Sample sizes: Chinook day=26-66, night=27-66 (period 9=5); steelhead day=23-78, night=17-44.

66, night = 5-66.

14.4% at the powerhouse, spillway and non-overflow wall, respectively. The proportions of first detections at the powerhouse were greater during the day than at night (Figure 3). This trend was relatively consistent throughout the 9-period study, except during period 2, in which the differences between the proportions of first detections at the powerhouse during the day and night were much greater than in the other periods. The proportions of first detections of yearling Chinook salmon at both the spillway and powerhouse were more similar during day and night periods than steelhead (Figure 3). More yearling Chinook salmon were first detected at the powerhouse in the day (mean 75%) than the night (mean 68%). The proportions of Chinook first detected at the spillway were similar during the day and night (15.0% versus 15.5%), but a greater proportion was first detected at the non-overflow wall at night (17.0%) than in the day (9.6%).

Behavior in the Near-Dam Forebay

Significant among-period differences were present in day and night residence times of juvenile steelhead (Kruskal-Wallis Tests, DF = 8 day and 7 night, all $P \leq 0.04$) and between the day periods of yearling Chinook salmon (Kruskal-Wallis Test, DF = 8, P =0.0007), requiring statistical analyses without pooling time periods. Results of this analysis indicate the median residence times in the near-dam forebay of fish arriving during the day were significantly longer than those of fish arriving at night (Friedman's test, DF = 1, all $P \leq 0.0002$). Median forebay residence times of juvenile steelhead in each time period ranged from 0.8 to 4.8 h if arriving during the day and from 0.2 to 0.9 h when arriving at night; median forebay residence times of fish arriving during the night were less variable than those arriving during the day (Figure 4). Median residence times of yearling Chinook salmon arriving during the day in each period ranged from 0.4 to 0.8 h and those arriving at night ranged from 0.3 to 0.6 h. The variability in residence times of yearling Chinook salmon arriving in the day and night were similar.

Fish less than 201 mm in fork length (FL) arriving during day spill had significantly shorter median forebay residence times than fish greater than 200 mm FL (0.8 versus 1.2 h; Kruskal-Wallis test, DF = 1, $P = 0.04$). These data may suggest that wild juvenile steelhead (typically < 200 mm FL) arriving at TDA during similar daytime spill conditions may pass the dam more quickly than their larger hatchery counterparts will. However, relatively few juvenile steelhead less than 201 mm FL were present in the data and no relation between fork length and residence time is evident in a plot of the data (Figure 5). The median residence times of juvenile steelhead of the two size groups arriving during the night were not significantly different (0.4 versus 0.5 h; Kruskal-Wallis test, DF = 1, $P = 0.21$).

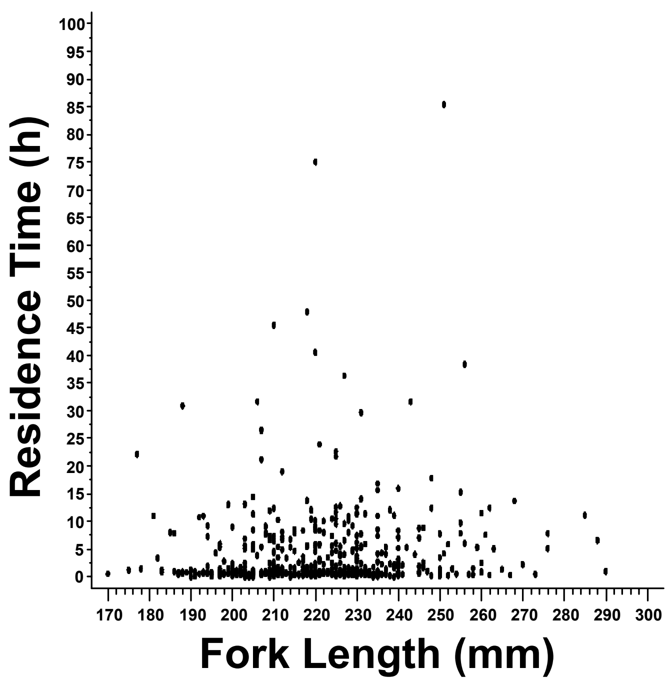

Figure 5. Forebay residence times of radio-tagged juvenile steelhead arriving at The Dalles Dam during 40% day spill (0700-1859 h) by fork length, 02 May through 01 June 2000.

General Route and Time of Passage

The time of day that radio-tagged fish passed TDA was dispersed throughout the diel period, though there were several peaks (Figure 6). A large proportion of juvenile steelhead passed between 0800 and 0959 h (16%) and between 2000 and 2159 (18%). Their passage was also slightly higher in the day than at night. The passage times of yearling Chinook salmon peaked between 0800 and 1159 h, but were relatively constant throughout the rest of the diel period.

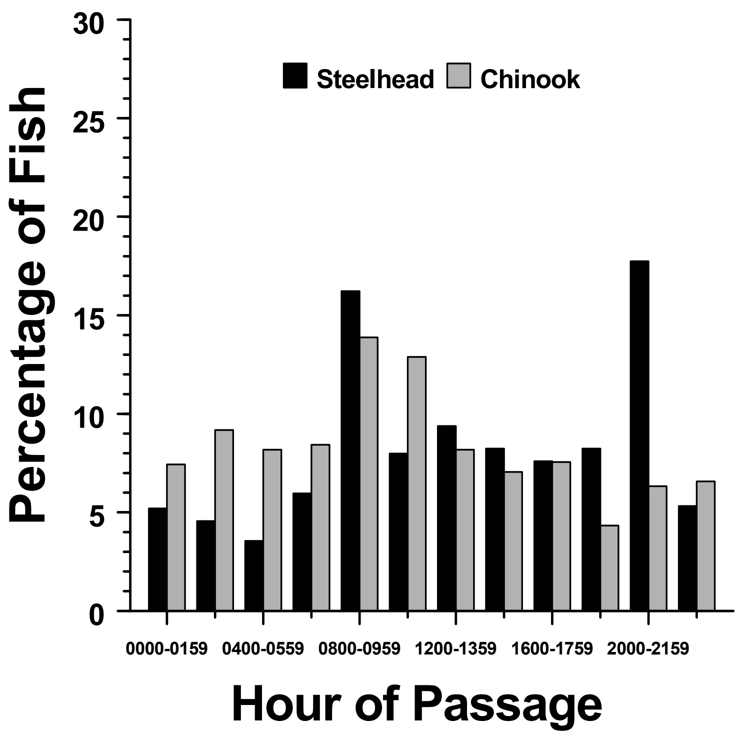

Figure 6. Diel distribution of radio-tagged juvenile steelhead and yearling Chinook salmon passage in the near-dam forebay of The Dalles Dam during 40% spill discharge, 02 May through 01 June 2000. Sample sizes: juvenile steelhead=789, yearling Chinook=807.

Overall, 86% percent of juvenile steelhead passed via the spillway, with 72% passing via the north half of the spillway and 14% passing via the south half. Six percent of the juvenile steelhead passed through the sluiceway and eight percent passed via the turbines. Turbine passage was 5% at the western half of the powerhouse and 3% at the eastern half. Data from yearling Chinook salmon indicate a similar pattern, with 80% passing via the spillway, 6% via the sluiceway, and 14% via the turbines. Sixty-three percent of the yearling Chinook salmon passed via the north half of the spillway and 17% passed via the south half. Nine percent of the yearling Chinook salmon passed via the turbines on the western half of the powerhouse and 5% passed through the eastern half.

Diel differences in the area of passage were evident, with proportionately more fish passing via the powerhouse and fewer via the spillway at night than in the day (Figure 7). Overall, 87.7% of the juvenile steelhead passing the dam during the day (day passage N = 438) were last detected at the spillway, 5.5% were last detected at the powerhouse and 6.8% were last detected in the sluiceway. At night, the proportions were 81.7, 13.5, and 4.8% at the spillway, powerhouse and sluiceway, respectively, indicating decreases in spillway and sluiceway passage and an increase in powerhouse passage at night (night passage N = 334). A reduction in spillway passage and an increase in powerhouse passage of yearling Chinook salmon at night was also evident, but unlike juvenile steelhead, the sluiceway passage of this species increased at night relative to the day. The proportions of yearling Chinook salmon passing via the spillway, sluiceway and powerhouse were 86.4, 10.0, and 3.6% during the day (day passage N = 442) and 71.4, 20.4, and 8.2% at night (night passage N = 343).

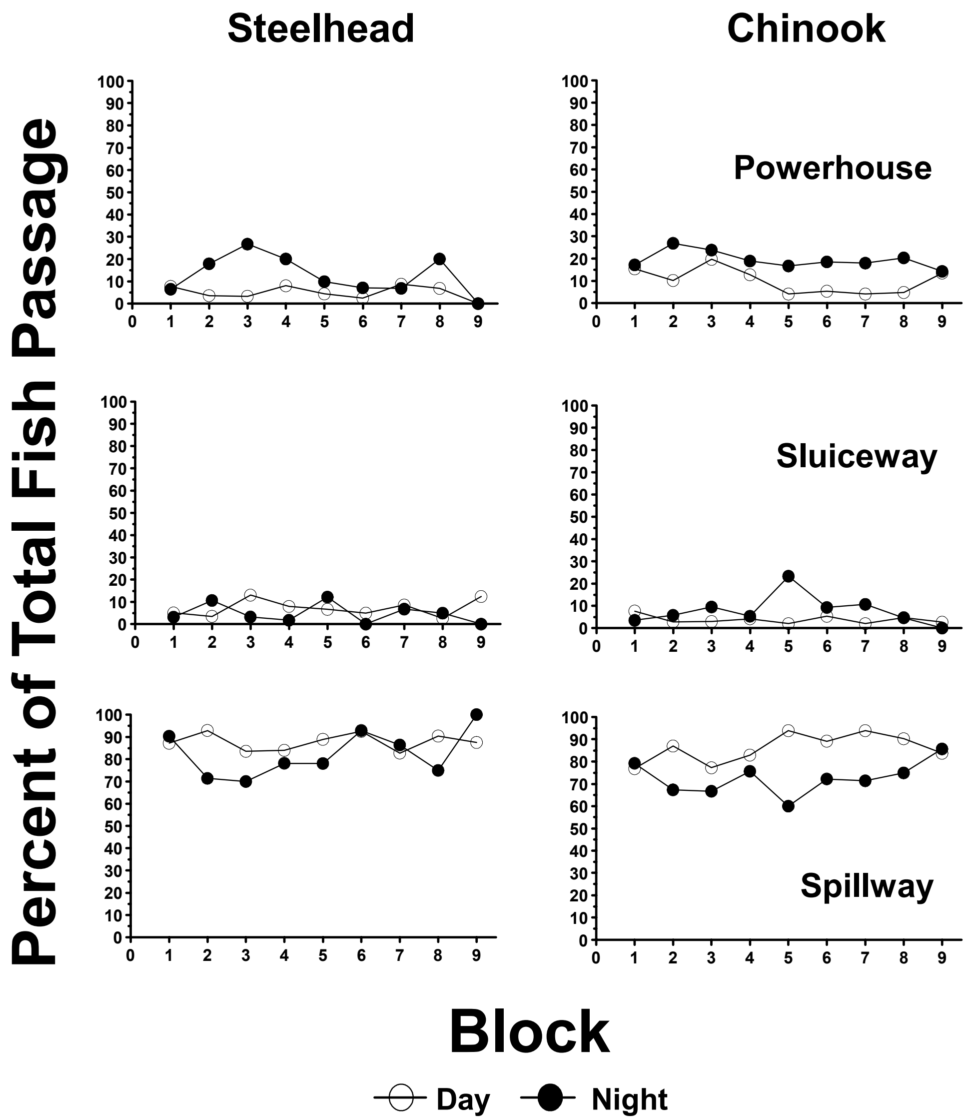

Figure 7. Percentage of radio-tagged juvenile steelhead and yearling Chinook salmon passing through the powerhouse, sluiceway, and spillway during day and night 40% spill discharge at The Dalles Dam, 02 May through 01 June 2000. Day= 0700-1859, Night=1900-0659. Sample sizes: steelhead day=16-73, night=9-56; Chinook day=37-69, night=7-64.

Fish-, Spill-, and Sluiceway-Passage Efficiencies

Statistically significant diel differences in FPE and SPE were present in data from juvenile steelhead, but no significant diel differences in SLPE of this species were detected. The diel difference in juvenile steelhead FPE was statistically significant based on the odds ratios of each time period ($P < 0.0001$; Table 3). The odds ratios of FPE comparisons in Table 3 were less than 1.0 in six of the nine study periods, indicating the FPE was lower during the night than in the day during these times. The night FPE estimates were more variable among time periods than those from the day (Figure 8). However, among-period effects were not significant, so the data were pooled to calculate an overall estimate. The overall (time periods pooled) FPE of juvenile steelhead was greater during the day (94.5%) than at night (86.5%; Table 4).

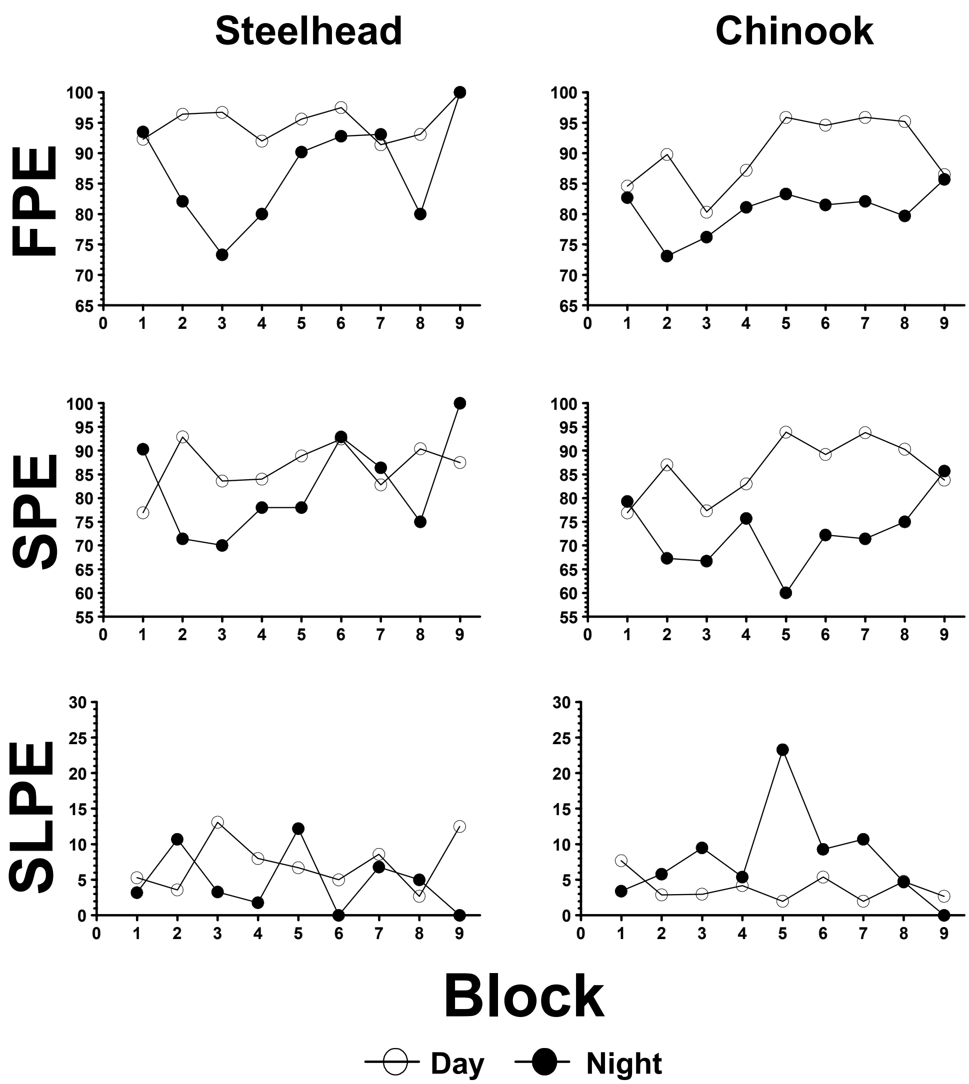

Figure 8. Juvenile steelhead and yearling Chinook salmon fish passage efficiency (FPE), spill passage efficiency (SPE), and sluiceway passage efficiency (SLPE) during continuous 40% spill discharge at The Dalles Dam, spring 2000. Blocks represent nine 3-day intervals from 02 May through 01 June except for block 9, which spans 6 days. Sample sizes are given in Table 4.

As in the FPE estimates, the SPE estimates were more consistent among time periods during the day than during the night (Figure 8; Table 3). The SPE of juvenile steelhead (adjusted for block effects) was significantly greater during the day than the night, resulting in a significant odds ratio (ratio = 0.588, $P = 0.0105$). The among-period effects in SPE were not significant, so the data were pooled to calculate an overall seasonal estimate. The overall estimate of SPE was 87.7% during the day and 81.7% at night (Table 4).

The SLPE of juvenile steelhead was not significantly different between day (6.8%) and night (4.8%) periods ($P = 0.3184$; Table 3; no significant among-period effects). Day and night SLPE estimates among time periods varied from near 0 to about 12% (Figure 8). Overall day and night estimates were 6.8% and 4.8%, respectively (Table 4).

The FPE and SPE of yearling Chinook salmon were significantly greater during the day than during the night (adjusting for variation among time periods), but the opposite pattern was present in SLPE. The day FPE and SPE estimates were consistently greater than the night indices among periods, but the day and night estimates were similar in period 1 and again in period 9 (Figure 8).

Table 3. Estimates (Est) of juvenile steelhead fish passage efficiency (FPE), spill passage efficiency (SPE), and sluiceway passage efficiency (SLPE), during day (0700-1859 h) and night (1900-0659 h) 40% spill discharge at The Dalles Dam, 02 May through 01 June 2000. N=sample size. Odds=Est/(100-Est). Odds ratio=$night_{odds}/day_{odds}$. LRCI = likelihood ratio confidence interval. Asterisks denote significant differences based on logistic regression adjusting for time periods. Periods 8 and 9 were combined for the FPE estimate.

		Diel Period						
		Day			Night			Observed
	Period	Est	N	Odds	Est	N	Odds	Odds Ratio
FPE	1	92.3	39	11.987	93.5	31	14.385	1.200
	2	96.4	56	26.778	82.1	28	4.587	0.171
	3	96.7	61	29.303	73.3	30	2.745	0.937
	4	92.0	50	11.500	80.0	55	4.000	0.348
	5	95.6	45	21.727	90.2	41	9.204	0.424
	6	97.5	40	39.000	92.9	56	13.085	0.335
	7	91.4	58	10.628	93.2	44	13.706	1.290
	8	94.4	89	16.857	83.7	49	5.135	0.303
	Overall odds ratio adjusted for periods 1-8 (95% LRCI)							0.350 (0.204-0.589)
	Test HO: odds ratio = 1 (no diel effect), P<0.0001*							
SPE	1	87.2	39	6.812	90.3	31	9.309	1.366
	2	92.9	56	13.084	71.4	28	2.496	0.191
	3	83.6	61	5.098	70.0	30	2.333	0.458
	4	84.0	50	5.250	78.2	55	3.587	0.683
	5	88.9	45	8.009	78.0	41	3.545	0.443
	6	92.5	40	12.333	92.9	56	13.084	1.061
	7	82.8	58	4.814	86.4	44	6.353	1.320
	8	90.4	73	9.417	75.0	40	3.000	0.319
	9	87.5	16	7.000	100.0	9	-	-
	Overall odds ratio adjusted for periods 1-9 (95% LRCI)							0.588 (0.390-0.883)
	Test HO: odds ratio = 1 (no diel effect), P=0.0105*							
SLPE	1	5.1	39	0.054	3.2	31	0.033	0.615
	2	3.6	56	0.037	10.7	28	0.120	3.209
	3	13.1	61	0.151	3.3	30	0.034	0.226
	4	8.0	50	0.087	1.8	55	0.018	0.211
	5	6.7	45	0.072	12.2	41	0.139	1.935
	6	5.0	40	0.053	0.0	56	0.000	0.000
	7	8.6	58	0.094	6.8	44	0.073	0.775
	8	2.7	73	0.028	5.0	40	0.053	1.897
	9	12.5	16	0.143	0.0	9	0.000	0.000
	Overall odds ratio adjusted for periods 1-9 (95% LRCI)							0.727 (0.377-1.354)
	Test HO: odds ratio = 1 (no diel effect), P=0.3184							

Table 4. Estimates (Est) of juvenile steelhead (STH) and yearling Chinook salmon (CH1) fish passage efficiency (FPE), spill passage efficiency (SPE), and sluiceway passage efficiency (SLPE) during day (0700-1859 h) and night (1900-0659 h) 40% spill discharge at The Dalles Dam, 02 May through 01 June 2000. N=sample size. LRCI = likelihood ratio confidence interval.

		Diel Period					
	Passage	Day			Night		
	efficiency	Est	95%LRCI	N	Est	95%LRCI	N
STH	FPE	94.5	92.1 – 96.4	438	86.5	82.6 – 89.9	334
	SPE	87.7	84.4 – 90.5	438	81.7	77.4 – 85.6	334
	SLPE	6.8	4.7 – 9.5	438	4.8	2.8 – 7.4	334
CH1	FPE	90.0	87.0 – 92.6	442	79.6	75.1 – 83.6	343
	SPE	86.4	83.0 – 89.4	442	71.4	66.5 – 76.0	343
	SLPE	3.6	2.1 – 5.6	442	8.2	5.6 – 11.4	343

The consistent diel differences in FPE among time periods resulted in an overall odds ratio less than 1.0 and a 95% confidence interval that did not encompass 1.0, indicating that FPE was significantly greater in the day than at night (Table 5; $P < 0.0001$). Block effects were not significant, so the data were pooled to calculate an overall FPE. The overall estimates of yearling Chinook salmon FPE were 90.0% in the day and 79.6% at night (Table 4).

Significant diel differences within SPE and SLPE of yearling Chinook salmon were present. The SPE estimates of yearling Chinook salmon were 86.4% during the day and 71.4% at night, with a pattern of day/night differences similar to the yearling Chinook salmon FPE data described above (Tables 4 and 5; Figure 8; $P < 0.0001$). The SLPE estimates were significantly lower during the day (3.6% over all periods) than at night (8.2% over all periods, $P = 0.0081$).

Table 5. Estimates (Est) of yearling Chinook salmon fish passage efficiency (FPE), spill passage efficiency (SPE), and sluiceway passage efficiency (SLPE) during day (0700-1859 h) and night (1900-0659 h) 40% spill discharge at The Dalles Dam, 02 May through 01 June 2000. N=sample size. Odds=Est/(100-Est). Odds ratio=$night_{odds}/day_{odds}$. LRCI = likelihood ratio confidence interval. Asterisks denote significant differences based on logistic regression adjusting for time periods.

		Diel Period						
		Day			Night			Observed
	Period	Est	N	Odds	Est	N	Odds	Odds Ratio
FPE	1	84.6	26	5.493	82.8	29	4.814	0.876
	2	89.9	69	8.901	73.1	52	2.717	0.305
	3	80.3	66	4.076	76.2	42	3.207	0.785
	4	87.2	47	6.812	81.1	37	4.291	0.630
	5	95.9	49	23.390	83.3	30	4.988	0.213
	6	94.6	37	17.518	81.5	54	4.405	0.251
	7	95.9	49	23.390	82.1	28	4.587	0.196
	8	95.2	62	19.833	79.7	64	3.926	0.198
	9	86.5	37	6.407	85.7	7	5.993	0.935
	Overall odds ratio adjusted for periods 1-9 (95% LRCI)							0.412 (0.269-0.624)
	Test HO: odds ratio = 1 (no diel effect), *P*<0.0001*							
SPE	1	76.9	26	3.329	79.3	29	3.831	1.151
	2	87.0	69	6.692	67.3	52	2.058	0.308
	3	77.3	66	3.405	66.7	42	2.003	0.588
	4	83.0	47	4.882	75.7	37	3.115	0.638
	5	93.9	49	15.393	60.0	30	1.500	0.097
	6	89.2	37	8.259	72.2	54	2.597	0.314
	7	93.9	49	15.393	71.4	28	2.496	0.162
	8	90.3	62	9.309	75.0	64	3.000	0.322
	9	83.8	37	5.173	85.7	7	5.993	1.159
	Overall odds ratio adjusted for periods 1-9 (95% LRCI)							0.380 (0.262-0.549)
	Test HO: odds ratio = 1 (no diel effect), *P*<0.0001*							
SLPE	1	7.7	26	0.083	3.4	29	0.035	0.422
	2	2.9	69	0.030	5.8	52	0.062	2.062
	3	3.0	66	0.031	9.5	42	0.105	3.394
	4	4.3	47	0.045	5.4	37	0.057	1.270
	5	2.0	49	0.020	2.3	30	0.024	1.154
	6	5.4	37	0.057	9.3	54	0.103	1.796
	7	2.0	49	0.020	10.7	28	0.120	5.871
	8	4.8	62	0.050	4.7	64	0.049	0.978
	9	2.7	37	0.028	0.0	7	0.000	0.000
	Overall odds ratio adjusted for periods 1-9 (95% LRCI)							2.344 (1.245-4.560)
	Test HO: odds ratio = 1 (no diel effect), *P*=0.0081*							

The spill effectiveness of both species was similar during the day, but was greater for juvenile steelhead than yearling Chinook salmon during the night. Spill effectiveness estimates were 2.2:1 for juvenile steelhead and yearling Chinook salmon during the day and were 2.1:1 for juvenile steelhead and 1.8:1 for yearling Chinook salmon during the night.

Detection efficiencies

The detection efficiencies of the arrays at the powerhouse, spillway, and sluiceway were not equal. The overall day and night detection efficiencies (forebay and tailrace arrays combined) of each of the species were 94% or greater at the powerhouse and over 99% at the spillway (Table 6). The efficiencies of the forebay arrays were greater than the tailrace arrays, as indicated by the small incidence of "01" capture histories relative the "10" histories in most cases. Most fish were detected on both arrays, as indicated by the large "11" capture histories

Table 6. Diel capture histories and detection probabilities of telemetry detection arrays at the powerhouse and spillway at The Dalles Dam, spring 2000. See text for capture history and detection probability definitions.

Capture History	Chinook Salmon				Steelhead			
	Powerhouse		Spillway		Powerhouse		Spillway	
	Day	Nite	Day	Nite	Da	Nite	Day	Nite
01	1	5	9	4	0	6	2	4
10	17	25	22	3	13	12	15	4
11	18	35	353	241	9	26	368	266
Total	36	65	384	248	22	44	385	274
Detection Probabilities								
P1	0.95	0.88	0.98	0.98	1.00	0.81	0.99	0.98
P2	0.51	0.58	0.94	0.99	0.41	0.68	0.96	0.98
P12	0.97	0.95	0.99	0.99	1.00	0.94	0.99	0.99

relative to the “01” and “10” histories. Overall detection efficiencies (i.e., *P12*) at the spillway were equal during day and night periods and those at the powerhouse differed by 2% for yearling Chinook salmon and 6% for juvenile steelhead, each being greater during the day than the night. However, the 6% difference in steelhead data from the powerhouse during the day had a much lower sample size than the other time periods, indicating that all tagged fish were detected by the forebay array.

The differences in detection probabilities between the spillway, powerhouse and sluiceway arrays (assumed sluiceway efficiency of 1.0) resulted in less than one percent difference in the passage index estimates (Table 7).

Table 7. Diel passage estimates from juvenile steelhead (STH) and yearling Chinook salmon (CH1) based on raw numbers of fish detected (Raw), after adjustments based on detection probabilities of each detection array (Adj) and the resulting difference (Diff). All numbers are percents.

	Estimate	Day			Night		
		Raw	Adj	Diff	Raw	Adj	Diff
STH	FPE	94.5	94.5	0	86.5	85.8	0.7
	SPE	87.7	87.7	0	81.7	81.0	0.7
	SLPE	6.8	6.8	0	4.8	4.7	0.1
CH1	FPE	90.0	89.8	0.2	79.6	78.7	0.9
	SPE	86.4	86.2	0.2	71.4	70.6	0.8
	SLPE	3.6	3.6	0	8.2	8.1	0.1

Discussion

The continuous 40% spill and juvenile spill pattern used in 2000 resulted in juvenile salmonid passage indices more similar to those of the 1999 64% spill treatment than the 1999 30% treatment. Juvenile steelhead and juvenile spring Chinook salmon FPE and SPE were lower at night than during the day and were accompanied by an opposite diel pattern in SLPE. The high FPE and SPE and low SLPE in 2000 relative to 1999 may be due to differences in spill patterns and spill discharge between years and day/night periods. This is indicated by the large difference between day and night FPE at the intermediate spill Q relative to the low and high spill Q in Figure 9A. We believe this is due to the differences in the day and night spill patterns at the three spill discharges and that the differences between day and night FPE at the low and high spill Q would have been greater if the juvenile pattern was used at those discharges during the day as well as the night. The night data at all spill discharges were collected during the juvenile pattern, the daytime data at the low and high spill discharges are from the adult spill pattern (1999) and all the data at the intermediate spill discharge are from the juvenile pattern (2000). Thus, the larger difference between day and night FPE at the intermediate spill discharge relative to the other discharges is likely due to differences in day and night spill patterns and indicates the juvenile spill pattern results in greater FPE than the adult pattern at similar spill discharges. Similar trends can also be seen in plots of yearling Chinook salmon SPE and SLPE, though the differences in SLPE are in the opposite direction because the juvenile pattern passes more fish via the spillway and reduces sluiceway passage compared to the adult pattern (Figures 9B and C). Differences in SPE and SLPE due to spill patterns are less evident in data from juvenile steelhead (Figure 9E and F).

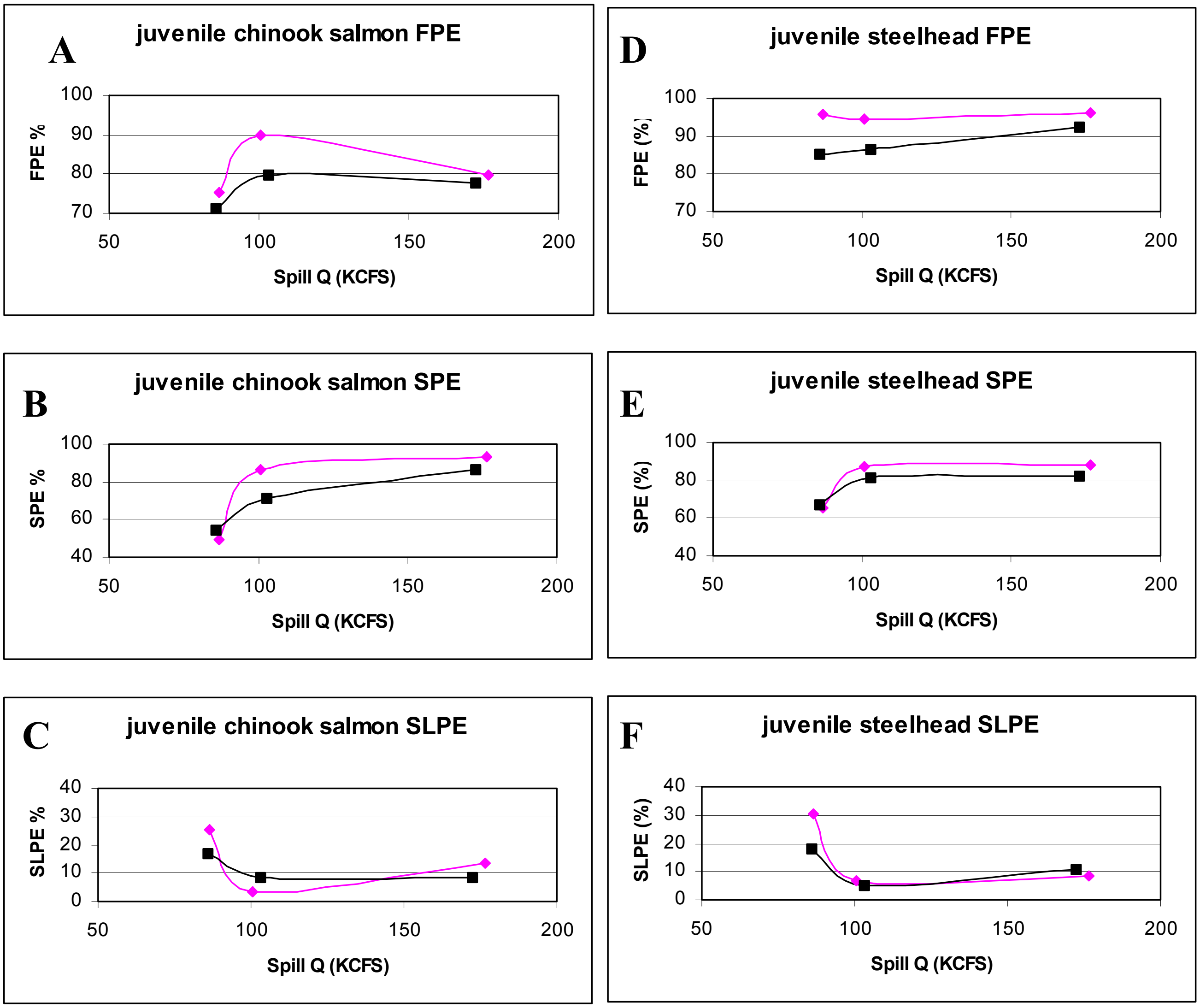

Figure 9. Fish passage efficiency (FPE), spill passage efficiency (SPE), and sluiceway passage efficiency (SLPE) estimates of juvenile spring Chinook salmon and juvenile steelhead plotted against spill discharge (spill Q) from USGS radio telemetry studies during 1999 and 2000. Data at the low and high spill Q are from 1999 30% spill and 64% spill, respectively; data at the intermediate spill Q are from 40% spill during 2000. The adult spill pattern was used during the day and the juvenile spill pattern was used at night in 1999; the juvenile spill pattern was used 24 h per day in 2000. Square symbols indicate nighttime values; diamond symbols indicate daytime values. Smoothed lines are fitted to the data.

Though the trends in Figure 9 are based on few data points, they are similar to those in data collected via hydroacoustic studies of fish passage in recent years summarized by Ploskey et al. (2001). The hydroacoustic results are based on a greater number of data points because the data are from thousands or millions of targets and can be divided into smaller periods for analysis. The plots in Figure 9 indicate little benefit in passage indices during the conditions tested above a spill discharge of approximately 100 KCFS, though few other conclusions can be drawn from Figure 9 because it only contains three data points per line. However, this is similar to the results of hydroacoustic data summarized by Ploskey et al. (2001) indicating the inflection point is at about 130 KCFS.

The SLPE estimates from 1999 and 2000 indicate a curvilinear reduction in SLPE with spill discharge, but the SLPE of yearling Chinook salmon was particularly low during the day in 2000 (Figure 9C, intermediate data points). This relatively low SLPE suggests that the juvenile spill pattern results in lower SLPE than the adult spill pattern at similar spill discharge.

Taken together, the FPE, SPE, and SLPE data from 1999 and 2000 indicate that at similar discharges the juvenile spill pattern results in greater FPE and SPE and concomitant reductions in SLPE compared to the adult spill pattern, presumably because spilling in this pattern effectively draws fish away from the powerhouse and the sluiceway entrance. The data also indicate that there was little change in the passage indices at spill discharges greater than roughly 100 KCFS during the test conditions, which is similar to the results of data summarized by Ploskey et al. (2001) indicating the inflection point is at about 130 KCFS.

Spill effectiveness in 2000 was greater than in 1999. Spill effectiveness of juvenile steelhead was equal to the 1999 30% spill value during the day (2.2:1), and was similar to the 1999 30% value at night (2.2:1 in 1999 versus 2.1:1 in 2000), indicating no change due to the different daytime spill patterns used in the two years (adult pattern in 1999 and juvenile pattern in 2000) as well as little change between spill percentages used, as comparisons of night values are not confounded by differences between spill patterns. The spill effectiveness of yearling Chinook salmon was greater in the day than the night in both 1999 and 2000, but the magnitude of the differences appear to be affected by spill patterns. For example, the 1999 spill effectiveness of yearling Chinook salmon during 30% spill was 1.6:1 during the day (adult spill pattern) and 1.8:1 at night (juvenile spill pattern). In 2000, the spill effectiveness was 2.2:1 in the day and 1.8:1 at night, indicating that the juvenile spill pattern during the day in 2000 resulted in a greater spill effectiveness than the adult pattern during the day in 1999. As expected, the values at night were similar during 1999 and 2000, because the juvenile pattern was used during this period in both years.

The estimates of FPE, SPE and SLPE were more consistent between time periods during the day than at night. This may be due to the differences in sample sizes of day and night estimates from each period. There was a greater number of tagged fish arriving and passing the dam during the day than at night, which resulted in larger sample sizes in estimates from day periods than night periods (Tables 4 and 5). However, this should not be construed as evidence of a diel passage difference of run-of-the-river fish, as the passage times of the tagged fish are dependent on their release times and locations, the arrival and passage times at John Day Dam of those released above that site, the travel time from release to The Dalles Dam and the residence time in the forebay of The Dalles Dam.

Forebay residence times of juvenile steelhead arriving during the day were shorter from fish less than 201 mm FL than those greater than that size. This may indicate that wild steelhead (typically less than 201 mm FL at John Day Dam) have shorter residence times than most hatchery steelhead. This was also noted in data from this study in 1999 (Hansel et al 2000) and in data from John Day Dam in 1999 and 2000 (Hansel et al. 2000; Beeman et al. 2003). A firm conclusion about the forebay residence times of wild steelhead cannot be drawn from these studies, because they were not designed to determine such differences and there was little data from hatchery-origin juvenile steelhead less than 201 mm FL. In addition, scatter plots of fish length versus residence time in 2000 do not indicate a visually identifiable relation between these variables. However, recent studies of fish passage do indicate forebay residence times of wild steelhead are shorter than those of hatchery steelhead at Lower Granite Dam (Adams et al. 1998; Adams and Rondorf 2001). For example, median residence times of wild steelhead in the forebay of Lower Granite Dam during spring 1997 were 0.66 h and those of hatchery steelhead were 0.83 h, a 12.5% difference (Adams et al. 1998). Median residence times of the two races in the forebay of Lower Granite Dam in 1998 differed by 24% (Adams and Rondorf 2001).

Adjusting the number of fish detected at the various arrays to account for differences in detection probabilities had little effect on the passage index estimates. This can be attributed to the similarity of the detection probabilities of the powerhouse and spillway arrays, which varied by no more than 6% within a diel period, and that most fish passed via the spillway, where detection probabilities were very high. One of the assumptions in using this method of calculating detection probabilities is that all detected fish are committed to a known route of passage. Aerial arrays are typically not used for this purpose, because their large detection area can result in detecting fish that are not committed to that passage route. However, we believe the separation of the powerhouse and spillway by the non-overflow wall at The Dalles Dam make their use acceptable in this case. Though somewhat of a circular argument, the high detection probability at the forebay arrays makes it unlikely that a fish missed by one array would go undetected at another. It is also relatively unlikely that a fish passing via the powerhouse would be detected by the aerial array in the spillway tailrace, and less likely that a fish passing via the spillway would be detected at the powerhouse tailrace.

The lack of a double array in the sluiceway prevented us from calculating the detection probabilities using passing tagged fish and we recommend a second array be added to the sluiceway in future studies. A detection probability of 1.00 was assumed used for the sluiceway array when adjusting for differences in detection probabilities of the various arrays, which is probably an overestimate. However, in 2000 the proportion of fish passing via the sluiceway was so small in comparison with the spillway that little or no difference in the outcome would be expected from reasonable differences in the detection efficiency of the sluiceway.

In summary, the 24-h 40% spill condition with the juvenile spill pattern used in 2000 resulted in higher FPE and SPE, but lower SLPE compared to 1999 results under varied treatments. The differences appear to be due to differences in the spill discharges as well as differences in passage due to spill patterns. The juvenile spill pattern appears to draw fish away from the powerhouse and sluiceway entrance and pass more fish via the spillway than the adult pattern used during the day in 1999. This trend was more evident in data from yearling Chinook salmon than data from juvenile steelhead, possibly because the spill effectiveness of yearling Chinook salmon is higher in the day than night, but that of juvenile steelhead is about equal during both periods. The results from this study, a similar study conducted in 1999, and hydroacoustic studies in recent years indicate that at the test conditions in these years little benefit in FPE, SPE, or SLPE at The Dalles Dam was gained by increasing spill discharge over approximately 100 to 130 KCFS.

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References

Adams, N. S., D. W. Rondorf and M. A. Tuell. 1998. Migrational characteristics of juvenile spring Chinook salmon and steelhead in the forebay of Lower Granite Dam relative to the 1997 surface bypass collector tests: final report for 1997. Prepared by the U.S. Geological Survey and the Nez Perce Tribe Department of Fisheries Resource Management for the U.S. Army Corps of Engineers, Walla Walla, Washington, USA.

Adams, N. S., and D. W. Rondorf. 2001. Juvenile Chinook salmon and steelhead passage in the forebay of Lower Granite Dam relative to the surface bypass collector and behavioral guidance structure tests. Prepared by the U.S. Geological Survey for the U.S. Army Corps of Engineers, Walla Walla, Washington, USA.

Allen, B., T. L. Liedtke, A. Daniel, J. Begala, M. Salway, A. McKinney, T. Baumgarte, J. Brady, E. Kinne, and J. Beeman. 2001. Movement, distribution and behavior of radio-tagged yearling Chinook salmon in the tailrace of The Dalles Dam, 2000. Prepared by the U.S. Geological Survey, Cook Washington for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Beeman, J. W., H. C. Hansel, P. V. Haner and J. Hardiman. 2003. Estimates of fish and spill passage efficiency of radio-tagged juvenile steelhead and yearling Chinook salmon at John Day Dam, 2000. Prepared by the U.S. Geological Survey, Cook Washington for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Duran, I. N., T. L. Liedtke, L. S. Brown, J. M. Drzewiecki, D. E. O'Donoghue, J. A. Quenette, E. M. Shoudel, J. P. Anderson, and J. Beeman. 2001. Movement, distributions and behavior of radio-tagged juvenile salmon at John Day Dam, 2000. U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

COE (U.S. Army Corps of Engineers), 2000. River Data. ONLINE. U.S. Army Corps of Engineers, Portland, Oregon, USA. Available:http://www.nwd-wc.usace.army.mil/-TMT/tdg_data/months.html [accessed July, 2000].

Hansel, H. C., J. W. Beeman, T. C. Counihan, B. D. Liedtke. M. S. Novick, and J. H. Plumb. 2000. Estimates of fish and spill passage efficiency of radio-tagged juvenile steelhead and yearling Chinook salmon at The Dalles Dam, 1999. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Hensleigh, J. E., R. S. Shively, H .C. Hansel, J. M. Hardiman, G. S. Holmberg, B. D. Liedtke, T. L. Martinelli, R. E. Wardell, R. H. Wertheimer, and T. P. Poe. 1999. Movement, distribution and behavior of radio-tagged juvenile Chinook salmon and steelhead in John Day, The Dalles and Bonneville dam forebays, 1997. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Holmberg, G. S., R. S. Shively, H. C. Hansel, T. L. Martinelli, M. B. Sheer, J. M. Hardiman, B. D. Liedtke, L. S. Blythe, and T. P. Poe. 1998. Movement, distribution, and behavior of radio-tagged juvenile Chinook salmon in John Day, The Dalles, and Bonneville forebays, 1996. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Lowther, A. B., and J. Skalski. 1997. The design and analysis of salmonid tagging studies in the Columbia Basin, Volume VIII. A new model for estimating survival probabilities and randomization from a release-recapture study of fall Chinook salmon (Oncorhynchus tshawytscha) smolts in the Snake River. Prepared by The University of Washington School of Fisheries, Seattle, Washington USA for the U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon, USA, contract DE-BI79-90BP02341.

Martinelli, T. L., H. C. Hansel, and R. S. Shively. 1998. Growth and physiological responses to surgical and gastric radio transmitter implantation techniques in subyearling Chinook salmon (*Oncorhynchus tshawytscha*). Hydrobiologia 371/372:79-87.

Martinelli, T. L. and R. S. Shively. 1997. Seasonal distribution, movements and habitat association of northern squawfish in two lower Columbia River reservoirs. Regulated Rivers Research and Management 13:543-556.

NMFS (National Marine Fisheries Service). 1998. Supplemental biological opinion: Operation of the federal Columbia River power system including the smolt monitoring program and the juvenile fish transportation program: A supplement to the Biological Opinion signed on March 2, 1995 for the same projects. Endangered Species Act – Section 7 Consultation, National Marine Fisheries Service, Northwest Region, Seattle, Washington, USA.

Ploskey, G., T. Poe, A. Giorgi and G. Johnson. 2001. Synthesis of Hydroacoustic, Radio Telemetry, and Survival Studies of Juvenile Salmon at The Dalles Dam (1882-2000). U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Sheer, M. B., G. S. Holmberg, R. S. Shively, T. P. King, C. N. Frost, H. C. Hansel, T. M. Martinelli, and T. P. Poe. 1997. Movement, distribution, and passage behavior of radio-tagged juvenile Chinook salmon in John Day and The Dalles Dam forebays, 1995. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Shively, R. S., T. P. Poe, and M. B. Sheer. 1996. Criteria for reducing predation by northern squawfish near juvenile salmonid bypass outfalls at Columbia River dams. Regulated Rivers Research and Management 12:493-500.

Whitney, R. R., L. D. Calvin, M. W. Erho, Jr., and C. C. Coutant. 1997. Downstream passage for salmon at hydroelectric projects in the Columbia River Basin: development, installation, and evaluation. Prepared for the Northwest Power Planning Council, Portland, Oregon, USA. #97-15.

Appendices

Appendix A. Mean planned and actual hourly spill and total river flow at The Dalles Dam during the spring study period in 2000. KCFS = thousand cubic feet per second.

Date	Hour	Planned Spill (%)	Spill (KCFS)	Total Flow (KCFS)	Actual Spill
1-May	1	40	115	282.3	40.7%
1-May	2	40	100	230.6	43.4%
1-May	3	40	80	195.4	40.9%
1-May	4	40	80	197.9	40.4%
1-May	5	40	80	199.5	40.1%
1-May	6	40	90	239.6	37.6%
1-May	7	40	104	237.3	43.8%
1-May	8	40	104	258.6	40.2%
1-May	9	40	104	261.8	39.7%
1-May	10	40	104	263.7	39.4%
1-May	11	40	104	262.2	39.7%
1-May	12	40	105	263.5	39.8%
1-May	13	40	105	266	39.5%
1-May	14	40	105	266.6	39.4%
1-May	15	40	105	292.7	35.9%
1-May	16	40	105	284.8	36.9%
1-May	17	40	105	276.2	38.0%
1-May	18	40	105	272.8	38.5%
1-May	19	40	105	290.8	36.1%
1-May	20	40	105	332.9	31.5%
1-May	21	40	105	363.3	28.9%
1-May	22	40	105	363.1	28.9%
1-May	23	40	105	351.2	29.9%
1-May	24	40	105	380.1	27.6%
2-May	1	40	105	356.7	29.4%
2-May	2	40	105	340.3	30.9%
2-May	3	40	105	313.3	33.5%
2-May	4	40	105	310.2	33.8%
2-May	5	40	105	322.6	32.5%
2-May	6	40	105	310.2	33.8%
2-May	7	40	105	246	42.7%
2-May	8	40	105	267.4	39.3%
2-May	9	40	105	256.2	41.0%
2-May	10	40	105	259.8	40.4%
2-May	11	40	105	259.5	40.5%
2-May	12	40	105	261.4	40.2%
2-May	13	40	105	265.1	39.6%
2-May	14	40	105	258.4	40.6%

2-May	15	40	105	260.2	40.4%
2-May	16	40	105	259.9	40.4%
2-May	17	40	100	256.2	39.0%
2-May	18	40	100	261.8	38.2%
2-May	19	40	100	319	31.3%
2-May	20	40	100	327	30.6%
2-May	21	40	100	322.8	31.0%
2-May	22	40	100	320.1	31.2%
2-May	23	40	100	307.8	32.5%
2-May	24	40	100	311	32.2%
3-May	1	40	100	301.2	33.2%
3-May	2	40	100	276.1	36.2%
3-May	3	40	100	276.2	36.2%
3-May	4	40	100	281.6	35.5%
3-May	5	40	100	322	31.1%
3-May	6	40	100	322.1	31.0%
3-May	7	40	100	360.9	27.7%
3-May	8	40	100	347.9	28.7%
3-May	9	40	100	314.7	31.8%
3-May	10	40	100	321.2	31.1%
3-May	11	40	100	288.7	34.6%
3-May	12	40	100	260.9	38.3%
3-May	13	40	100	251.2	39.8%
3-May	14	40	100	251.6	39.7%
3-May	15	40	96	236	40.7%
3-May	16	40	90	219.5	41.0%
3-May	17	40	90	220.1	40.9%
3-May	18	40	90	214.8	41.9%
3-May	19	40	100	245.5	40.7%
3-May	20	40	100	263.4	38.0%
3-May	21	40	100	299.4	33.4%
3-May	22	40	100	322.5	31.0%
3-May	23	40	100	321.6	31.1%
3-May	24	40	100	286.2	34.9%
4-May	1	40	100	309.3	32.3%
4-May	2	40	100	313.6	31.9%
4-May	3	40	100	322.3	31.0%
4-May	4	40	100	341	29.3%
4-May	5	40	100	341.3	29.3%
4-May	6	40	100	326.8	30.6%
4-May	7	40	100	331.1	30.2%
4-May	8	40	100	250.3	40.0%
4-May	9	40	100	252.5	39.6%
4-May	10	40	100	243.8	41.0%

4-May	11	40	92	224	41.1%
4-May	12	40	92	226.1	40.7%
4-May	13	40	92	229.5	40.1%
4-May	14	40	100	251.2	39.8%
4-May	15	40	100	246.5	40.6%
4-May	16	40	100	271.8	36.8%
4-May	17	40	108	277.2	39.0%
4-May	18	40	108	279	38.7%
4-May	19	40	120	333.2	36.0%
4-May	20	40	120	330.9	36.3%
4-May	21	40	120	356.1	33.7%
4-May	22	40	120	356.1	33.7%
4-May	23	40	120	334.1	35.9%
4-May	24	40	120	308.2	38.9%
5-May	1	40	114	293.9	38.8%
5-May	2	40	114	292.2	39.0%
5-May	3	40	110	277.5	39.6%
5-May	4	40	110	270.9	40.6%
5-May	5	40	102	260	39.2%
5-May	6	40	102	258.6	39.4%
5-May	7	40	102	260.9	39.1%
5-May	8	40	150	381.7	39.3%
5-May	9	40	150	394.2	38.1%
5-May	10	40	145	364.1	39.8%
5-May	11	40	120	302.4	39.7%
5-May	12	40	110	276.5	39.8%
5-May	13	40	110	276.2	39.8%
5-May	14	40	110	278.4	39.5%
5-May	15	40	110	278.4	39.5%
5-May	16	40	120	294.7	40.7%
5-May	17	40	120	305.1	39.3%
5-May	18	40	120	391.8	30.6%
5-May	19	40	118	329.9	35.8%
5-May	20	40	118	303.2	38.9%
5-May	21	40	118	303.9	38.8%
5-May	22	40	118	292.7	40.3%
5-May	23	40	118	279.3	42.2%
5-May	24	40	104	256.1	40.6%
6-May	1	40	104	256.2	40.6%
6-May	2	40	104	257.6	40.4%
6-May	3	40	104	253.3	41.1%
6-May	4	40	104	250.5	41.5%
6-May	5	40	104	258.4	40.2%
6-May	6	40	104	256.4	40.6%

6-May	7	40	118	296.6	39.8%
6-May	8	40	118	302.4	39.0%
6-May	9	40	118	299.3	39.4%
6-May	10	40	118	298	39.6%
6-May	11	40	118	310.7	38.0%
6-May	12	40	118	298	39.6%
6-May	13	40	118	298.7	39.5%
6-May	14	40	118	298.2	39.6%
6-May	15	40	118	297.1	39.7%
6-May	16	40	118	301.5	39.1%
6-May	17	40	125	306.9	40.7%
6-May	18	40	118	298.2	39.6%
6-May	19	40	118	308.1	38.3%
6-May	20	40	118	301.6	39.1%
6-May	21	40	118	305.8	38.6%
6-May	22	40	118	302.9	39.0%
6-May	23	40	118	297.1	39.7%
6-May	24	40	140	298.7	46.9%
7-May	1	40	140	313.8	44.6%
7-May	2	40	140	317	44.2%
7-May	3	40	115	293.2	39.2%
7-May	4	40	105	264.9	39.6%
7-May	5	40	105	275	38.2%
7-May	6	40	105	269	39.0%
7-May	0	40	100	245.5	40.7%
7-May	8	40	100	230.6	43.4%
7-May	9	40	100	231.5	43.2%
7-May	10	40	100	250.2	40.0%
7-May	11	40	115	272.7	42.2%
7-May	12	40	115	276.5	41.6%
7-May	13	40	100	243.1	41.1%
7-May	14	40	100	244.4	40.9%
7-May	15	40	100	240.8	41.5%
7-May	16	40	115	294.4	39.1%
7-May	17	40	115	289.7	39.7%
7-May	18	40	105	262	40.1%
7-May	19	40	105	256.9	40.9%
7-May	20	40	105	259.6	40.4%
7-May	21	40	124	306.2	40.5%
7-May	22	40	124	304.9	40.7%
7-May	23	40	100	244.2	41.0%
7-May	24	40	90	216.4	41.6%
8-May	1	40	90	219.4	41.0%
8-May	2	40	90	223.8	40.2%

8-May	3	40	90	226.8	39.7%
8-May	4	40	90	229.7	39.2%
8-May	5	40	90	228.2	39.4%
8-May	6	40	90	233.6	38.5%
8-May	7	40	114	270.8	42.1%
8-May	8	40	114	312.2	36.5%
8-May	9	40	114	299.3	38.1%
8-May	10	40	114	336.7	33.9%
8-May	11	40	125	349.4	35.8%
8-May	12	40	100	262.7	38.1%
8-May	13	40	100	248.4	40.3%
8-May	14	40	100	245.5	40.7%
8-May	15	40	100	262	38.2%
8-May	16	40	100	244.8	40.8%
8-May	17	40	100	242.6	41.2%
8-May	18	40	100	252	39.7%
8-May	19	40	100	261.7	38.2%
8-May	20	40	120	295.2	40.7%
8-May	21	40	120	298.9	40.1%
8-May	22	40	120	301.9	39.7%
8-May	23	40	120	293.4	40.9%
8-May	24	40	120	291.3	41.2%
9-May	1	40	120	297.6	40.3%
9-May	2	40	120	296.7	40.4%
9-May	3	40	110	279	39.4%
9-May	4	40	110	277.6	39.6%
9-May	5	40	110	273.9	40.2%
9-May	6	40	120	300.6	39.9%
9-May	7	40	120	295.5	40.6%
9-May	8	40	120	339	35.4%
9-May	9	40	130	352	36.9%
9-May	10	40	130	347.2	37.4%
9-May	11	40	114	302.5	37.7%
9-May	12	40	114	290.7	39.2%
9-May	13	40	114	288.1	39.6%
9-May	14	40	114	288.3	39.5%
9-May	15	40	108	287.4	37.6%
9-May	16	40	108	316.3	34.1%
9-May	17	40	95	252.7	37.6%
9-May	18	40	95	229.6	41.4%
9-May	19	40	95	239.8	39.6%
9-May	20	40	80	241.8	33.1%
9-May	21	40	80	241.7	33.1%
9-May	22	40	96	240.2	40.0%

9-May	23	40	96	226.8	42.3%
9-May	24	40	96	232.7	41.3%
10-May	1	40	96	234.7	40.9%
10-May	2	40	96	224.6	42.7%
10-May	3	40	88	230.8	38.1%
10-May	4	40	80	195.9	40.8%
10-May	5	40	80	197	40.6%
10-May	6	40	80	205.1	39.0%
10-May	7	40	88	213.5	41.2%
10-May	8	40	100	254.6	39.3%
10-May	9	40	110	278.8	39.5%
10-May	10	40	110	278.7	39.5%
10-May	11	40	110	274.7	40.0%
10-May	12	40	104	265.2	39.2%
10-May	13	40	100	260.1	38.4%
10-May	14	40	100	261.8	38.2%
10-May	15	40	100	265.9	37.6%
10-May	16	40	100	260.1	38.4%
10-May	17	40	100	265.4	37.7%
10-May	18	40	100	257.8	38.8%
10-May	19	40	112	283.6	39.5%
10-May	20	40	112	283.9	39.5%
10-May	21	40	112	293.3	38.2%
10-May	22	40	110	273.3	40.2%
10-May	23	40	110	280.8	39.2%
10-May	24	40	96	233.8	41.1%
11-May	1	40	96	227.4	42.2%
11-May	2	40	96	232.4	41.3%
11-May	3	40	96	245.1	39.2%
11-May	4	40	84	207	40.6%
11-May	5	40	84	205.5	40.9%
11-May	6	40	84	212.3	39.6%
11-May	7	40	100	244.5	40.9%
11-May	8	40	115	305.1	37.7%
11-May	9	40	115	302.8	38.0%
11-May	10	40	115	298.3	38.6%
11-May	11	40	115	290.6	39.6%
11-May	12	40	115	292.6	39.3%
11-May	13	40	115	288.4	39.9%
11-May	14	40	105	270.6	38.8%
11-May	15	40	105	255.7	41.1%
11-May	16	40	105	255.5	41.1%
11-May	17	40	105	260.7	40.3%
11-May	18	40	105	260.3	40.3%

11-May	19	40	105	266.9	39.3%
11-May	20	40	105	271.9	38.6%
11-May	21	40	105	285.7	36.8%
11-May	22	40	120	298.4	40.2%
11-May	23	40	100	247.8	40.4%
11-May	24	40	100	244.5	40.9%
12-May	1	40	100	247.9	40.3%
12-May	2	40	100	248.9	40.2%
12-May	3	40	100	253.5	39.4%
12-May	4	40	100	250.5	39.9%
12-May	5	40	100	250.5	39.9%
12-May	6	40	100	255.3	39.2%
12-May	7	40	125	308.6	40.5%
12-May	8	40	125	320.4	39.0%
12-May	9	40	125	321.1	38.9%
12-May	10	40	125	308.7	40.5%
12-May	11	40	125	296	42.2%
12-May	12	40	105	269.2	39.0%
12-May	13	40	105	267.5	39.3%
12-May	14	40	105	267.7	39.2%
12-May	15	40	105	268.2	39.1%
12-May	16	40	105	258.2	40.7%
12-May	17	40	105	259	40.5%
12-May	18	40	105	264.8	39.7%
12-May	19	40	105	259.4	40.5%
12-May	20	40	105	259	40.5%
12-May	21	40	105	274.7	38.2%
12-May	22	40	105	274.7	38.2%
12-May	23	40	110	283.9	38.7%
12-May	24	40	110	269.1	40.9%
13-May	1	40	106	262.5	40.4%
13-May	2	40	98	242.2	40.5%
13-May	3	40	92	229.3	40.1%
13-May	4	40	92	226.6	40.6%
13-May	5	40	92	227.8	40.4%
13-May	6	40	92	227.5	40.4%
13-May	7	40	92	227.3	40.5%
13-May	8	40	92	228.2	40.3%
13-May	9	40	92	225.5	40.8%
13-May	10	40	92	228	40.4%
13-May	11	40	92	225.5	40.8%
13-May	12	40	88	214.6	41.0%
13-May	13	40	88	215.1	40.9%
13-May	14	40	88	216.8	40.6%

13-May	15	40	88	215.4	40.9%
13-May	16	40	88	216.8	40.6%
13-May	17	40	88	216.8	40.6%
13-May	18	40	88	215.3	40.9%
13-May	19	40	100	249	40.2%
13-May	20	40	100	245.8	40.7%
13-May	21	40	100	246	40.7%
13-May	22	40	100	244.1	41.0%
13-May	23	40	100	250.8	39.9%
13-May	24	40	100	243.3	41.1%
14-May	1	40	100	243.8	41.0%
14-May	2	40	100	243.8	41.0%
14-May	3	40	100	245.3	40.8%
14-May	4	40	100	243.8	41.0%
14-May	5	40	100	245.7	40.7%
14-May	6	40	105	256.1	41.0%
14-May	7	40	105	255.3	41.1%
14-May	8	40	105	258.9	40.6%
14-May	9	40	96	241	39.8%
14-May	10	40	96	240.6	39.9%
14-May	11	40	96	236.2	40.6%
14-May	12	40	96	240.4	39.9%
14-May	13	40	96	241	39.8%
14-May	14	40	104	259.9	40.0%
14-May	15	40	104	257.2	40.4%
14-May	16	40	104	257.2	40.4%
14-May	17	40	90	224.3	40.1%
14-May	18	40	90	225.4	39.9%
14-May	19	40	114	285.7	39.9%
14-May	20	40	114	290.8	39.2%
14-May	21	40	120	307.5	39.0%
14-May	22	40	120	306.5	39.2%
14-May	23	40	120	307.2	39.1%
14-May	24	40	120	300.5	39.9%
15-May	1	40	120	306.6	39.1%
15-May	2	40	106	269.4	39.3%
15-May	3	40	106	263.4	40.2%
15-May	4	40	94	235.9	39.8%
15-May	5	40	94	238.7	39.4%
15-May	6	40	108	278.2	38.8%
15-May	7	40	108	277.4	38.9%
15-May	8	40	108	259.3	41.7%
15-May	9	40	100	250	40.0%
15-May	10	40	100	248.9	40.2%

15-May	11	40	90	224.8	40.0%
15-May	12	40	90	227.1	39.6%
15-May	13	40	90	224.8	40.0%
15-May	14	40	90	224.3	40.1%
15-May	15	40	90	221.8	40.6%
15-May	16	40	90	221.3	40.7%
15-May	17	40	90	222.5	40.4%
15-May	18	40	90	225.8	39.9%
15-May	19	40	130	334.6	38.9%
15-May	20	40	130	320.1	40.6%
15-May	21	40	120	301.1	39.9%
15-May	22	40	120	298.9	40.1%
15-May	23	40	120	295.1	40.7%
15-May	24	40	120	295.6	40.6%
16-May	1	40	120	297.6	40.3%
16-May	2	40	120	295	40.7%
16-May	3	40	105	261.5	40.2%
16-May	4	40	105	261	40.2%
16-May	5	40	105	260.4	40.3%
16-May	6	40	105	261.1	40.2%
16-May	7	40	100	250.7	39.9%
16-May	8	40	100	253.6	39.4%
16-May	9	40	100	250.9	39.9%
16-May	10	40	100	241.3	41.4%
16-May	11	40	100	238.4	41.9%
16-May	12	40	92	227.6	40.4%
16-May	13	40	92	225.6	40.8%
16-May	14	40	92	226.1	40.7%
16-May	15	40	92	215.9	42.6%
16-May	16	40	80	202.6	39.5%
16-May	17	40	80	189.4	42.2%
16-May	18	40	80	184	43.5%
16-May	19	40	72	179.5	40.1%
16-May	20	40	88	230.8	38.1%
16-May	21	40	88	224.2	39.3%
16-May	22	40	88	222.7	39.5%
16-May	23	40	88	209.3	42.0%
16-May	24	40	88	210.8	41.7%
17-May	1	40	80	196.4	40.7%
17-May	2	40	80	201.4	39.7%
17-May	3	40	80	201.5	39.7%
17-May	4	40	84	207.8	40.4%
17-May	5	40	84	210.4	39.9%
17-May	6	40	88	227.2	38.7%

17-May	7	40	100	261.2	38.3%
17-May	8	40	100	258.7	38.7%
17-May	9	40	97	247.8	39.1%
17-May	10	40	97	246.6	39.3%
17-May	11	40	97	247.1	39.3%
17-May	12	40	97	246.8	39.3%
17-May	13	40	97	248.7	39.0%
17-May	14	40	97	248.1	39.1%
17-May	15	40	97	251.4	38.6%
17-May	16	40	97	256	37.9%
17-May	17	40	97	254.7	38.1%
17-May	18	40	97	254.5	38.1%
17-May	19	40	97	253.9	38.2%
17-May	20	40	97	256.7	37.8%
17-May	21	40	97	250.4	38.7%
17-May	22	40	97	245.9	39.4%
17-May	23	40	97	245.6	39.5%
17-May	24	40	97	230.7	42.0%
18-May	1	40	97	223.3	43.4%
18-May	2	40	85	199.1	42.7%
18-May	3	40	85	199.6	42.6%
18-May	4	40	85	200.6	42.4%
18-May	5	40	95	223	42.6%
18-May	6	40	95	225	42.2%
18-May	7	40	99	243.6	40.6%
18-May	8	40	99	236.2	41.9%
18-May	9	40	99	234.3	42.3%
18-May	10	40	99	234	42.3%
18-May	11	40	99	242.9	40.8%
18-May	12	40	104	249	41.8%
18-May	13	40	104	259.1	40.1%
18-May	14	40	104	273.1	38.1%
18-May	15	40	104	266.3	39.1%
18-May	16	40	112	282.4	39.7%
18-May	17	40	112	281.3	39.8%
18-May	18	40	112	278.2	40.3%
18-May	19	40	112	281.7	39.8%
18-May	20	40	112	287.2	39.0%
18-May	21	40	112	285.8	39.2%
18-May	22	40	112	286.3	39.1%
18-May	23	40	112	283.9	39.5%
18-May	24	40	112	261	42.9%
19-May	1	40	98	244.6	40.1%
19-May	2	40	86	214.9	40.0%

19-May	3	40	86	211.7	40.6%
19-May	4	40	86	213.6	40.3%
19-May	5	40	86	211.6	40.6%
19-May	6	40	86	212.4	40.5%
19-May	7	40	86	212.4	40.5%
19-May	8	40	86	215.8	39.9%
19-May	9	40	86	214.1	40.2%
19-May	10	40	92	229.3	40.1%
19-May	11	40	92	226.6	40.6%
19-May	12	40	92	226.4	40.6%
19-May	13	40	92	227.5	40.4%
19-May	14	40	92	227.3	40.5%
19-May	15	40	92	227	40.5%
19-May	16	40	92	230.5	39.9%
19-May	17	40	92	229.5	40.1%
19-May	18	40	92	232.6	39.6%
19-May	19	40	104	259	40.2%
19-May	20	40	104	267.4	38.9%
19-May	21	40	105	277.9	37.8%
19-May	22	40	105	276.4	38.0%
19-May	23	40	105	258.8	40.6%
19-May	24	40	105	261.2	40.2%
20-May	1	40	96	245.1	39.2%
20-May	2	40	96	242.6	39.6%
20-May	3	40	96	241	39.8%
20-May	4	40	96	241.5	39.8%
20-May	5	40	96	241.9	39.7%
20-May	6	40	96	246.1	39.0%
20-May	7	40	88	218.8	40.2%
20-May	8	40	88	222.6	39.5%
20-May	9	40	88	221.1	39.8%
20-May	10	40	84	210.6	39.9%
20-May	11	40	84	210.4	39.9%
20-May	12	40	84	209	40.2%
20-May	13	40	84	211.3	39.8%
20-May	14	40	84	209.6	40.1%
20-May	15	40	84	207.5	40.5%
20-May	16	40	84	212.3	39.6%
20-May	17	40	84	211.7	39.7%
20-May	18	40	84	213.8	39.3%
20-May	19	40	112	285.6	39.2%
20-May	20	40	112	285.6	39.2%
20-May	21	40	112	283.9	39.5%
20-May	22	40	112	283.9	39.5%

20-May	23	40	112	278	40.3%
20-May	24	40	112	266.5	42.0%
21-May	1	40	112	281.1	39.8%
21-May	2	40	112	282.4	39.7%
21-May	3	40	112	281.9	39.7%
21-May	4	40	112	278.5	40.2%
21-May	5	40	112	277.6	40.3%
21-May	6	40	112	280.8	39.9%
21-May	7	40	120	282.4	42.5%
21-May	8	40	120	302.8	39.6%
21-May	9	40	120	301.9	39.7%
21-May	10	40	104	261.7	39.7%
21-May	11	40	104	265.7	39.1%
21-May	12	40	88	221	39.8%
21-May	13	40	68	174.2	39.0%
21-May	14	40	68	167.3	40.6%
21-May	15	40	68	167.4	40.6%
21-May	16	40	68	169.1	40.2%
21-May	17	40	68	171.5	39.7%
21-May	18	40	68	175.2	38.8%
21-May	19	40	80	193.6	41.3%
21-May	20	40	92	236.1	39.0%
21-May	21	40	96	243.8	39.4%
21-May	22	40	96	255.2	37.6%
21-May	23	40	104	257.6	40.4%
21-May	24	40	108	253.7	42.6%
22-May	1	40	108	273	39.6%
22-May	2	40	108	275.3	39.2%
22-May	3	40	108	274.3	39.4%
22-May	4	40	98	246	39.8%
22-May	5	40	88	219.1	40.2%
22-May	6	40	88	219	40.2%
22-May	7	40	88	202.9	43.4%
22-May	8	40	88	223.3	39.4%
22-May	9	40	96	241.7	39.7%
22-May	10	40	96	241.2	39.8%
22-May	11	40	86	208.1	41.3%
22-May	12	40	86	214.6	40.1%
22-May	13	40	86	214.2	40.1%
22-May	14	40	86	217.8	39.5%
22-May	15	40	86	210.6	40.8%
22-May	16	40	86	232.4	37.0%
22-May	17	40	86	232.4	37.0%
22-May	18	40	86	231.2	37.2%

22-May	19	40	86	229.6	37.5%
22-May	20	40	86	235.5	36.5%
22-May	21	40	108	269.3	40.1%
22-May	22	40	108	274.9	39.3%
22-May	23	40	108	273.4	39.5%
22-May	24	40	108	267.5	40.4%
23-May	1	40	108	272.6	39.6%
23-May	2	40	108	271.5	39.8%
23-May	3	40	108	269.8	40.0%
23-May	4	40	96	239.5	40.1%
23-May	5	40	96	239.5	40.1%
23-May	6	40	96	240.3	40.0%
23-May	7	40	96	225.9	42.5%
23-May	8	40	116	246.9	47.0%
23-May	9	40	116	300.5	38.6%
23-May	10	40	116	302.1	38.4%
23-May	11	40	116	324.1	35.8%
23-May	12	40	116	301.5	38.5%
23-May	13	40	116	300.8	38.6%
23-May	14	40	116	300.7	38.6%
23-May	15	40	116	293.9	39.5%
23-May	16	40	116	300.3	38.6%
23-May	17	40	116	305.5	38.0%
23-May	18	40	116	300.6	38.6%
23-May	19	40	120	308.9	38.8%
23-May	20	40	120	314.3	38.2%
23-May	21	40	120	309	38.8%
23-May	22	40	120	303.5	39.5%
23-May	23	40	120	310.9	38.6%
23-May	24	40	120	294.8	40.7%
24-May	1	40	106	261.7	40.5%
24-May	2	40	106	261.5	40.5%
24-May	3	40	106	261.3	40.6%
24-May	4	40	106	261.1	40.6%
24-May	5	40	106	261.3	40.6%
24-May	6	40	106	260.5	40.7%
24-May	7	40	106	251	42.2%
24-May	8	40	106	259.1	40.9%
24-May	9	40	106	264.4	40.1%
24-May	10	40	106	262.5	40.4%
24-May	11	40	106	264.9	40.0%
24-May	12	40	106	264.4	40.1%
24-May	13	40	106	263.9	40.2%
24-May	14	40	106	265.6	39.9%

24-May	15	40	106	273.3	38.8%
24-May	16	40	106	276.3	38.4%
24-May	17	40	106	275.4	38.5%
24-May	18	40	106	274.8	38.6%
24-May	19	40	116	301.4	38.5%
24-May	20	40	116	294.1	39.4%
24-May	21	40	116	299.6	38.7%
24-May	22	40	116	295.9	39.2%
24-May	23	40	116	298.9	38.8%
24-May	24	40	116	301.2	38.5%
25-May	1	40	116	288.8	40.2%
25-May	2	40	108	276.6	39.0%
25-May	3	40	108	271.3	39.8%
25-May	4	40	108	269.4	40.1%
25-May	5	40	108	272.8	39.6%
25-May	6	40	108	269.6	40.1%
25-May	7	40	104	251.3	41.4%
25-May	8	40	104	259.9	40.0%
25-May	9	40	108	271.3	39.8%
25-May	10	40	108	271.5	39.8%
25-May	11	40	108	268.4	40.2%
25-May	12	40	108	268.9	40.2%
25-May	13	40	108	268.8	40.2%
25-May	14	40	108	276.1	39.1%
25-May	15	40	108	277.7	38.9%
25-May	16	40	108	270.2	40.0%
25-May	17	40	108	265	40.8%
25-May	18	40	108	275.3	39.2%
25-May	19	40	117	294.7	39.7%
25-May	20	40	117	292.6	40.0%
25-May	21	40	117	291.6	40.1%
25-May	22	40	117	288.8	40.5%
25-May	23	40	96	238.5	40.3%
25-May	24	40	96	237.9	40.4%
26-May	1	40	96	233	41.2%
26-May	2	40	96	234	41.0%
26-May	3	40	96	238.1	40.3%
26-May	4	40	96	238.6	40.2%
26-May	5	40	96	238.8	40.2%
26-May	6	40	96	238.8	40.2%
26-May	7	40	96	239	40.2%
26-May	8	40	96	239.6	40.1%
26-May	9	40	96	239.3	40.1%
26-May	10	40	96	238.6	40.2%

26-May	11	40	80	199.8	40.0%
26-May	12	40	80	194.9	41.0%
26-May	13	40	80	196.2	40.8%
26-May	14	40	74	190.5	38.8%
26-May	15	40	74	181.8	40.7%
26-May	16	40	74	179.3	41.3%
26-May	17	40	74	191.6	38.6%
26-May	18	40	74	180.3	41.0%
26-May	19	40	74	179.8	41.2%
26-May	20	40	74	184.6	40.1%
26-May	21	40	74	182.2	40.6%
26-May	22	40	74	184.9	40.0%
26-May	23	40	80	196.4	40.7%
26-May	24	40	80	202.3	39.5%
27-May	1	40	86	212.7	40.4%
27-May	2	40	86	214.3	40.1%
27-May	3	40	92	229.2	40.1%
27-May	4	40	92	232	39.7%
27-May	5	40	96	241.1	39.8%
27-May	6	40	96	241	39.8%
27-May	7	40	96	241	39.8%
27-May	8	40	96	243.1	39.5%
27-May	9	40	96	244.4	39.3%
27-May	10	40	96	246.5	38.9%
27-May	11	40	96	244.9	39.2%
27-May	12	40	96	246	39.0%
27-May	13	40	96	242.3	39.6%
27-May	14	40	96	241.1	39.8%
27-May	15	40	96	234.8	40.9%
27-May	16	40	96	234.4	41.0%
27-May	17	40	96	242.5	39.6%
27-May	18	40	82	211.3	38.8%
27-May	19	40	82	211	38.9%
27-May	20	40	82	214	38.3%
27-May	21	40	82	210.7	38.9%
27-May	22	40	82	212.7	38.6%
27-May	23	40	82	206.2	39.8%
27-May	24	40	82	188.5	43.5%
28-May	1	40	94	240.1	39.2%
28-May	2	40	94	227.6	41.3%
28-May	3	40	94	234.9	40.0%
28-May	4	40	94	239.5	39.2%
28-May	5	40	94	237.8	39.5%
28-May	6	40	88	222.5	39.6%

28-May	7	40	72	176.8	40.7%
28-May	8	40	72	185.8	38.8%
28-May	9	40	84	214.9	39.1%
28-May	10	40	94	233.9	40.2%
28-May	11	40	94	243.2	38.7%
28-May	12	40	94	232.7	40.4%
28-May	13	40	94	234.4	40.1%
28-May	14	40	94	235.9	39.8%
28-May	15	40	94	222.4	42.3%
28-May	16	40	94	236.2	39.8%
28-May	17	40	94	239.2	39.3%
28-May	18	40	94	239.2	39.3%
28-May	19	40	94	240	39.2%
28-May	20	40	94	240.7	39.1%
28-May	21	40	94	244.8	38.4%
28-May	22	40	100	241.9	41.3%
28-May	23	40	88	230.6	38.2%
28-May	24	40	88	214.4	41.0%
29-May	1	40	88	218.4	40.3%
29-May	2	40	88	213.8	41.2%
29-May	3	40	80	206.6	38.7%
29-May	4	40	80	198.9	40.2%
29-May	5	40	80	198.7	40.3%
29-May	6	40	80	196.4	40.7%
29-May	7	40	70	171.6	40.8%
29-May	8	40	70	172	40.7%
29-May	9	40	65	161.8	40.2%
29-May	10	40	65	163	39.9%
29-May	11	40	65	159.4	40.8%
29-May	12	40	65	161.6	40.2%
29-May	13	40	76	190.1	40.0%
29-May	14	40	76	189.4	40.1%
29-May	15	40	76	190.4	39.9%
29-May	16	40	76	191.6	39.7%
29-May	17	40	76	187.4	40.6%
29-May	18	40	76	186.1	40.8%
29-May	19	40	76	189.9	40.0%
29-May	20	40	76	189.6	40.1%
29-May	21	40	88	228.6	38.5%
29-May	22	40	88	221.2	39.8%
29-May	23	40	88	213.2	41.3%
29-May	24	40	88	222.8	39.5%
30-May	1	40	76	191.8	39.6%
30-May	2	40	76	184.1	41.3%

30-May	3	40	76	189.5	40.1%
30-May	4	40	76	191.7	39.6%
30-May	5	40	88	218.9	40.2%
30-May	6	40	88	218.6	40.3%
30-May	7	40	88	221.4	39.7%
30-May	8	40	92	224.3	41.0%
30-May	9	40	92	231.9	39.7%
30-May	10	40	96	237.4	40.4%
30-May	11	40	96	233.8	41.1%
30-May	12	40	96	240.7	39.9%
30-May	13	40	96	248.3	38.7%
30-May	14	40	92	231	39.8%
30-May	15	40	92	223.7	41.1%
30-May	16	40	88	219.5	40.1%
30-May	17	40	88	208	42.3%
30-May	18	40	80	199.7	40.1%
30-May	19	40	80	204.7	39.1%
30-May	20	40	80	201.8	39.6%
30-May	21	40	100	257.1	38.9%
30-May	22	40	100	254.8	39.2%
30-May	23	40	100	256.6	39.0%
30-May	24	40	100	253.4	39.5%
31-May	1	40	100	251	39.8%
31-May	2	40	88	225.3	39.1%
31-May	3	40	88	226.2	38.9%
31-May	4	40	88	220.2	40.0%
31-May	5	40	88	220.3	39.9%
31-May	6	40	88	215.2	40.9%
31-May	7	40	88	222.2	39.6%
31-May	8	40	88	216.9	40.6%
31-May	9	40	88	215.4	40.9%
31-May	10	40	88	216.7	40.6%
31-May	11	40	88	216.4	40.7%
31-May	12	40	92	232.4	39.6%
31-May	13	40	92	229.9	40.0%
31-May	14	40	92	230	40.0%
31-May	15	40	92	227.7	40.4%
31-May	16	40	92	230.7	39.9%
31-May	17	40	100	249.7	40.0%
31-May	18	40	100	250.6	39.9%
31-May	19	40	100	253.1	39.5%
31-May	20	40	104	259.9	40.0%
31-May	21	40	104	260.3	40.0%
31-May	22	40	104	260.1	40.0%

31-May	23	40	112	282.8	39.6%
31-May	24	40	112	282.2	39.7%
		Mean	**100.1**	**255.3**	**39.4%**

Appendix B. Summary of the number of radio-tagged juvenile steelhead released (N) at Rock Creek, Washington, during spring 2000, and the mean, standard deviation (SD), and range of the fork length (mm) and weight (g).

Release date	Release time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
5/01/00	20:00	11	227	43	121-285	116.	41.9	69.7-200.5
5/02/00	08:00	13	220	14	191-253	89.3	15.4	62.1-127.5
5/03/00	08:00	13	222	15	195-245	91.2	18.8	62.0-127.2
5/03/00	20:00	14	223	19	185-254	93.6	24.4	54.5-136.9
5/04/00	20:00	13	221	18	195-265	88.5	23.6	61.7-147.0
5/05/00	08:00	14	229	16	194-258	104.	24.1	56.4-155.1
5/06/00	08:00	15	219	20	180-250	88.8	25.3	45.6-148.5
5/06/00	20:00	16	224	21	197-262	93.6	29.1	60.5-162.2
5/07/00	20:00	15	218	18	187-260	83.8	22.3	48.1-138.5
5/08/00	08:00	15	222	16	197-252	90.7	23.0	58.0-125.3
5/09/00	08:00	13	220	16	187-246	92.2	19.7	57.5-125.7
5/09/00	20:00	15	222	24	186-262	95.8	35.0	49.9-163.0
5/10/00	20:00	14	216	18	191-252	85.2	20.8	55.4-121.3
5/11/00	08:00	19	223	15	200-261	94.7	21.9	63.5-158.7
5/12/00	08:00	15	226	20	205-270	96.5	27.7	67.2-170.6
5/12/00	20:00	20	224	22	188-262	94.4	29.6	54.4-166.4
5/13/00	20:00	14	231	18	199-263	99.2	18.8	68.8-132.6
5/14/00	08:00	13	218	17	187-248	90.9	22.4	50.6-132.2
5/15/00	08:00	11	221	20	182-247	92.2	23.1	52.9-126.1
5/15/00	20:00	10	213	20	185-246	83.4	25.4	49.7-128.3
5/16/00	20:00	20	215	19	185-247	83.7	23.0	52.0-125.5
5/17/00	08:00	15	213	18	191-256	83.2	26.6	56.9-161.4
5/18/00	08:00	16	226	20	200-276	95.8	28.5	63.6-175.0
5/18/00	20:00	20	224	14	202-258	93.0	18.5	70.2-144.8
5/19/00	20:00	20	212	14	193-253	74.9	19.0	56.6-144.4
5/20/00	08:00	20	216	19	189-267	83.7	22.3	47.5-148.0
5/21/00	08:00	20	209	31	103-257	82.3	29.0	51.3-164.0
5/21/00	20:00	16	216	15	189-246	74.5	18.4	46.4-122.0
5/22/00	20:00	14	229	20	195-260	80.7	25.0	44.5-127.5
5/23/00	08:00	14	226	21	197-257	65.5	17.4	43.5-98.4
5/24/00	08:00	16	218	22	183-276	84.4	34.1	46.4-197.7
5/24/00	20:00	12	215	21	183-250	83.9	26.8	46.6-128.7
Overall		486	220	20	103-285	88.7	25.7	43.5-200.5

Appendix C. Summary of the number of radio-tagged yearling Chinook salmon (N) at Rock Creek, Washington, during spring 2000, and the mean, standard deviation (SD), and range of the fork length (mm) and weight (g).

Release date	Release time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
5/01/00	20:00	14	156	20	128-187	40.1	16.1	21.8-71.5
5/02/00	08:00	14	172	21	142-205	52.1	19.1	30.2-84.3
5/03/00	08:00	12	163	19	142-196	44.1	16.3	25.4-71.7
5/03/00	20:00	15	165	18	143-195	45.3	17.6	27.0-76.5
5/04/00	20:00	15	162	20	138-212	42.9	21.4	25.1-104.2
5/05/00	08:00	16	162	19	137-198	43.8	15.3	25.1-78.3
5/06/00	08:00	15	160	15	141-194	41.6	14.4	28.8-80.0
5/06/00	20:00	15	164	20	140-198	44.7	16.7	25.0-75.8
5/07/00	20:00	14	176	19	131-197	56.5	17.4	22.3-81.2
5/08/00	08:00	16	160	17	131-189	42.5	13.1	22.8-66.4
5/09/00	08:00	13	169	17	145-197	50.2	15.9	33.2-76.1
5/09/00	20:00	10	167	16	143-192	49.3	14.0	28.9-72.9
5/10/00	20:00	15	176	16	155-208	56.0	17.4	36.4-98.8
5/11/00	08:00	15	166	20	131-203	48.3	18.5	22.3-92.5
5/12/00	08:00	18	188	15	166-214	67.9	17.8	37.7-102.8
5/12/00	20:00	14	191	17	165-225	72.5	21.8	45.2-125.1
5/13/00	20:00	17	186	19	140-215	65.3	19.4	24.0-103.5
5/14/00	08:00	16	184	18	143-218	65.3	19.7	26.7-99.1
5/15/00	08:00	17	183	18	130-204	62.3	17.8	21.4-87.8
5/15/00	20:00	16	173	16	138-197	54.5	16.2	27.9-91.8
5/16/00	20:00	16	177	18	142-202	57.2	17.9	25.6-89.3
5/17/00	08:00	6	177	22	144-198	54.7	20.1	26.8-77.4
5/18/00	08:00	19	185	11	164-200	63.3	12.3	41.0-85.5
5/18/00	20:00	16	183	13	153-205	62.7	13.8	34.1-86.5
5/19/00	20:00	13	184	14	158-204	60.1	12.1	42.7-79.9
5/20/00	08:00	14	185	10	165-201	64.4	11.7	44.2-86.4
5/21/00	08:00	15	189	14	165-218	63.4	13.7	42.8-89.9
5/21/00	20:00	15	188	12	165-210	54.7	9.4	37.1-73.8
5/22/00	20:00	15	179	14	153-198	48.0	11.2	30.4-61.6
5/23/00	08:00	16	184	17	148-206	42.8	10.2	21.2-57.5
5/24/00	08:00	18	190	10	161-204	66.7	9.7	40.3-77.6
5/24/00	20:00	24	183	17	140-210	60.2	15.7	24.6-93.7
Overall		484	176	19	128-225	55.0	18.0	21.2-125.1

Appendix D. Summary of the number of radio-tagged juvenile steelhead released (N) in the John Day Dam tailrace during spring 2000, and the mean, standard deviation (SD), and range of the fork length (mm) and weight (g).

Release Date	Release Time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
5/02/00	20:00	19	222	30	122-263	100.	24.9	63.0-153.8
5/04/00	08:00	16	221	25	183-273	92.7	32.4	48.1-173.2
5/05/00	20:00	17	222	15	190-250	95.2	20.8	55.7-130.7
5/07/00	08:00	19	222	18	190-225	93.4	23.0	54.9-139.5
5/08/00	20:00	19	215	30	107-240	91.0	18.7	54.1-126.6
5/10/00	08:00	18	216	18	178-252	84.4	22.3	45.8-134.9
5/11/00	20:00	18	222	22	188-288	93.8	35.7	53.6-204.2
5/13/00	08:00	19	217	12	199-243	89.5	16.8	60.4-132.5
5/14/00	20:00	20	219	24	178-268	90.3	29.7	46.0-165.2
5/16/00	08:00	19	210	16	186-240	79.0	19.0	54.3-114.6
5/17/00	20:00	15	211	12	190-240	78.7	12.8	59.5-104.2
5/19/00	08:00	18	216	10	198-233	81.3	12.6	59.2-103.3
5/20/00	20:00	20	219	23	188-290	88.6	34.8	49.2-205.4
5/22/00	08:00	14	223	22	175-255	75.5	22.4	36.5-112.0
5/23/00	20:00	19	214	15	190-248	54.6	11.7	37.7-79.2
5/25/00	08:00	16	223	20	195-270	95.7	31.5	60.3-183.0
Overall		286	218	20	107-290	86.5	26.1	36.5-205.4

Appendix E. Summary of the number of radio-tagged yearling Chinook salmon released (N) in the John Day Dam tailrace during spring 2000, and the mean, standard deviation (SD), and range of the fork length (mm) and weight (g).

Release Date	Release Time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
5/02/00	20:00	17	153	13	125-176	36.5	9.1	21.5-56.5
5/04/00	08:00	17	158	11	142-187	38.2	10.6	23.9-70.7
5/05/00	20:00	15	162	17	125-190	48.5	14.3	29.7-71.4
5/07/00	08:00	17	172	16	133-199	54.0	14.8	26.8-86.1
5/08/00	20:00	19	178	24	146-222	58.8	23.4	28.9-102.6
5/10/00	08:00	18	184	19	156-218	65.1	21.2	36.2-104.0
5/11/00	20:00	16	174	22	145-220	54.4	21.9	30.2-108.3
5/13/00	08:00	18	184	16	151-207	64.8	17.7	31.8-94.7
5/14/00	20:00	19	177	19	141-210	58.4	18.3	29.0-92.6
5/16/00	08:00	19	178	24	140-215	58.8	22.4	24.5-91.8
5/17/00	20:00	9	184	19	146-218	65.4	17.9	33.9-97.1
5/19/00	08:00	19	176	20	140-207	55.3	20.1	21.1-85.2
5/20/00	20:00	19	182	12	162-206	59.1	12.4	40.3-81.8
5/22/00	08:00	14	175	15	147-195	42.8	10.7	22.8-58.1
5/23/00	20:00	24	185	13	156-205	45.8	9.7	26.1-63.0
5/25/00	08:00	25	182	16	143-220	60.9	13.5	33.3-98.7
Overall		284	176	19	125-222	54.3	18.5	21.1-108.3

Appendix F. Summary of the number of radio-tagged juvenile steelhead released (N) into spillbays or the juvenile-fish-bypass system as part of the John Day Dam egress study, spring 2000, and mean, standard deviation (SD) and range of fork length (mm) and weight (g).

Release date	Release time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
4/25/00	2200	22	208	16	177-240	79.6	17.1	49.5-122.4
5/01/00	2200	22	221	23	170-260	94.7	32.9	42.7-154.0
5/12/00	1000	23	217	19	117-251	88.0	24.9	44.2-142.0
5/17/00	1000	22	209	12	189-233	76.7	12.3	59.8-105.8
5/21/00	2200	23	218	13	194-250	87.2	14.4	62.1-116.6
5/24/00	1000	26	216	19	166-250	81.7	21.8	38.0-132.4
Overall		138	215	18	166-260	84.6	22.1	38.0-154.0

Appendix G. Summary of the number of radio-tagged yearling Chinook salmon (N) into spillbays or the juvenile-fish-bypass system as part of the John Day Dam egress study, spring 2000, and mean, standard deviation (SD) and range of fork length (mm) and weight (g).

Release date	Release time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
4/28/00	10:00	28	158	11	142-183	42.5	9.3	28.5-62.8
5/04/00	22:00	22	177	16	144-203	59.7	17.7	29.1-91.8
5/07/00	10:00	21	171	18	145-207	52.9	16.5	30.2-93.3
5/09/00	22:00	22	179	13	157-196	59.0	13.9	38.0-84.5
5/19/00	10:00	17	175	22	142-206	53.7	18.7	26.4-77.5
5/26/00	22:00	34	181	14	153-212	59.3	14.6	34.4-88.9
Overall		144	173	17	142-212	54.5	22.1	26.4-93.3